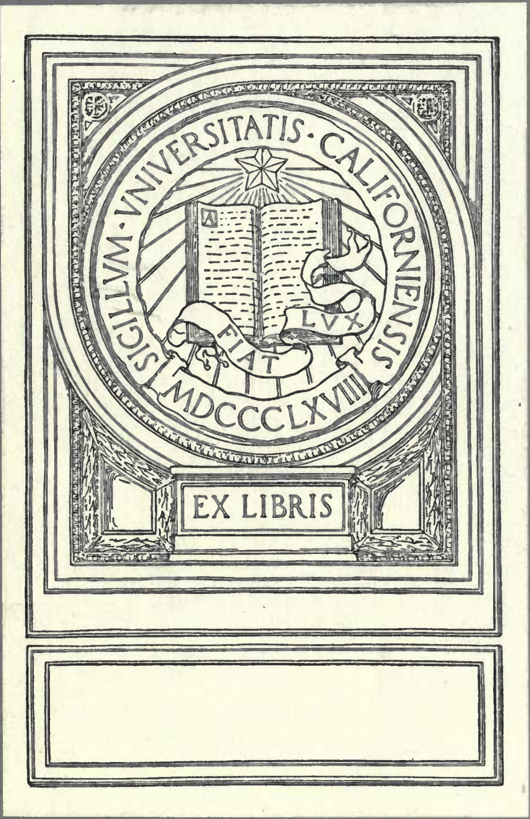
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Massachusetts, Geological survey

REPORT

ON A

RE-EXAMINATION

OF THE

ECONOMICAL GEOLOGY

OF

MASSACHUSETTS.

BY EDWARD HITCHCOCK,

PROFESSOR OF CHEMISTRY AND NATURAL HISTORY IN AMHERST COLLEGE.

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REPORT.

To His Excellency EDWARD EVERETT,
Governor of Massachusetts:

SIR,—The commission with which I was honored, to make a further Geological and Mineralogical survey of the State, was not received in season to enable me to enter upon the work till towards the conclusion of the last summer. From that time to the present, I have devoted myself to it almost without cessation.

I was directed to give special attention to five leading objects. The first was the collection and analysis of our soils, with a view to their improvement on chemical principles. The second was the discovery of coal, marl, and ores. The third was a re-examination of some of the rock formations, so as to determine more accurately their limits, that they may be colored on the new Geographical Map of the State. The fourth was to make further investigations into our scientific geology, both with a view to advance the science, and to make a practical application of any new discoveries that might be made. The fifth was the procuring of new specimens of our rocks and minerals for the State collection.

It was obvious at once, that it would be impossible to accomplish all these objects in one season. Indeed, in regard to the third object, which in the commencement of the geological survey was regarded as the main one, want of time was not the greatest obstacle. For it never can be effected until the geologist can obtain at least an outline map, far more accurate than any that now exists, except of one or two counties in the vicinity of Boston. It is an established principle, whose correctness will be seen on a moment's reflection, that a geological map cannot be made more accurate than the geographical

one which is made its basis. Hence but little progress can be made in the third object of my commission, until the new geographical map shall be so far advanced, that I can be furnished with its outlines at least.

Under these circumstances, and agreeably to your Excellency's instructions, I have made the soils, the marls, and the ores of the State, the leading object of my labors the last season. But in doing this, it was in my power to accomplish much in respect to all the other objects above named. To collect the soils, it was necessary to visit almost every part of the State; and I have been enabled, while doing this, to trace out more accurately the boundaries of several of the rock formations; to obtain several hundred specimens for the State collection; to examine many new and deeply interesting facts illustrative of the science of geology, and to procure several new sketches of our scenery. But I am totally unprepared to report upon any part of the subject, except our economical geology*: and even here I would most gladly have delayed my report till I could have examined some localities farther, and verified the analytical results which I shall present by farther experiments. During the last season I sent a circular to every town in the State, directed generally, to some gentleman who was a member of the Legislature last year, requesting information on certain points, which would require a vast amount of time to examine personally. The prompt manner in which the gentlemen addressed have complied with my request, has been gratifying; and for the important facts which they have communicated, I feel grateful. Even up to

*In connection with specimens of our soils, marls, &c. which I have deposited in the rooms of the Boston Natural History Society with the State collection, I take the liberty to ask the attention of the government to a few specimens, illustrating our scientific geology, which I have sent to the same place, because I thought they might be interesting. Two of them (Nos. 218, 219) are examples of the tracks of animals on stone, found in the region of Connecticut river. The one which is in relief, (No. 218) is of so monstrous a size (four times larger than the track of the Ostrich) that probably many can hardly be made to believe that it exhibits only the natural size of the foot of the animal that made it. Yet I can assure them, that if they will accompany me to the banks of Connecticut river, in Northampton, I can show them six tracks of the same size, four feet apart and following one another in succession ! No 219, is a smaller specimen which exhibits a very perfect example of a track in its natural position. The specimen No. 216, is a variety of the Emerald from a new locality recently discovered in Royalston. For a knowledge of this locality, as well as for assistance in obtaining specimens, I am much indebted to Alden Spooner, Esq. of Athol. It is certainly one of the finest gems which our country has produced. No. 217 is a specimen of Amethyst from Mr. Mortimer Blake of Franklin, and was found in that town. He assures me that it is much inferior to specimens which he has found there.

the time of making out this report, I have continued to receive new specimens of much interest;—some of which I have analyzed; but the localities I have not visited, both for want of time, and on account of the unfavorableness of the season of the year. As it has been impossible for me in all cases to communicate by letter, when requested, my opinion of the nature and value of the specimens sent by various gentlemen, I take the liberty to refer them for that opinion to this report, should it be printed; and also to say, that I shall take the earliest opportunity in my power to visit the localities.

In this report, I shall confine myself to those substances valuable to the State in a pecuniary point of view, *which have been discovered, or their value more fully developed, since the completion of my former Reports.* In this way the government will have a fair opportunity of judging whether this work is important enough to receive their patronage till it is completed.

1. Soils, *their Origin and Nature.*

Before proceeding to exhibit details respecting the soils of Massachusetts, it will be necessary to state my views respecting the origin and nature of soils in general, and the principles on which they may be classified.

All geologists and chemists agree in regarding soils as the result of the abrasion, disintegration, and decomposition of rocks, with the addition of certain saline, vegetable, and animal substances. Ever since the deposition of rocks, various agents have been operating upon them to wear them down, to cause them to crumble or disintegrate, and often to decompose them into their proximate or ultimate principles, while they have been constantly receiving vegetable and animal substances with soluble salts. The earthy portions, however, always constitute by far the largest part; and hence, if we know the composition of the rocks whence they were derived, we shall know the earthy and metallic constituents of the soil. Now we find that nearly all the rocks which exist in large quantity, are composed chiefly of silica, alumina, lime, and oxide of iron; and these are the ingredients that are found almost invariably in soils. Magnesia is also usually present in small quantity; as is also manganese in the soils of New England. Silica is in the largest quantity, both in the

rocks and the soils; alumina next; while the other ingredients are in much smaller proportion. I ought, also, to add potassa and soda; which are very widely diffused, though not usually in large quantity. To give a numerical statement, derived from numerous analyses, such rocks as most of those in New England contain 66 per cent of silica, 16 per cent of alumina, 6 or 7 per cent of potassa, 5 per cent of oxide of iron, and of lime and magnesia a much less quantity: and the composition of our soils will probably be found to correspond very nearly with these numbers, with the exception, perhaps, of the potassa, which may have in a good measure disappeared by the operation of vegetation.

Classification of Soils.

The above ingredients are combined in different proportions in the different rocks, so as to constitute several sorts. Hence we should expect, and in fact we find, a corresponding difference in the soils resulting from their decomposition. Indeed, with some exceptions, the geologist is able to ascertain the nature of the rock from the character of the soil that covers it. And I apprehend that it will not be difficult to point out the characteristics of the soils derived from the different rock formations of Massachusetts; so that they can be distinguished by those not familiar with practical geology. This Geological Classification is the only one which I shall attempt to give of our soils; and this seems to me all that is necessary, or useful, in addition to the common division into sandy, clayey, loamy, calcareous, &c. The following list embraces, it appears to me, all the important varieties of soil in Massachusetts.

1. Alluvium, from rivers.
   Do. peaty.
2. Tertiary soil, argillaceous.
   Do. sandy.
3. Sandstone soil, red.
   Do. gray.
4. Graywacke soil, conglomerate.
   Do. slaty, gray.
   Do. slaty, red.
5. Clay slate soil.

6. Limestone soil, magnesian.
   Do. common.
7. Mica slate soil.
8. Talcose slate soil.
9. Gneiss soil, common.
   Do. ferruginous.
10. Granite soil.
11. Sienite soil.
12. Porphyry soil.
13. Greenstone soil.

A few paragraphs of explanation will, I trust, render these varieties of soil recognizable.

In general, if any one wishes to know where to find them, let him look at the Geological Map that accompanied my former Report, and he may conclude that the different soils cover those portions of the surface that are represented as occupied by the rocks from which they are derived. There is one circumstance, however, that prevents us from considering the boundaries of the rock formations as perfectly coincident with those of the soils. Diluvial action has removed nearly all the loose covering of our rocks in a southerly direction; often several miles; and more or less mingled the soils from different formations. Hence, where one formation lies north or south of another on the map, we may conclude that the detritus of the most northerly one has been swept southerly, or southeasterly, for several miles beyond the boundaries of the rock; and in few cases does the dividing line between two formations so exactly coincide with the direction of the diluvial current, that there is no overlapping and intermingling of the soil. Where the formations are limited and irregular, the soil of whole townships is of so mixed and uncertain a character, that it is hardly possible to refer it to any of the above divisions; as for example in Amherst, Ludlow, and several of the towns in Plymouth county. In such cases, it might perhaps be convenient to call the soil *diluvial:* but I have not thought it important to introduce such a variety, since it can have no constant characters, and since this difficulty is of so limited a nature. In all such cases it is better to regard the soil as a compound of detritus from the rocks lying in the vicinity to the northward.

With common alluvial soils—the result of deposition from rivers,

—every intelligent man is familiar. They are of course formed by the comminution of every kind of rock over which the stream that produces them happens to pass. These soils, I apprehend, owe their value chiefly to the fine state to which their component parts are reduced. They may be made so fine as to exclude too much the access of air: and this seems to be the case with some of the soils upon our large rivers at the West. In Massachusetts our alluvia are frequently coarse and quite siliceous.

Peat alluvium is composed principally of vegetable matter, and ought rather to be regarded as a manure than a soil. I include in it all those swamps that abound in decomposing vegetable matter, whether actually converted into peat or not.

The principal deposites of the tertiary soils are in the valley of Connecticut river, and in the counties of Plymouth, Barnstable, Dukes and Nantucket. The surface in these places is usually covered with a white or yellowish siliceous sand, which forms one variety of these soils. Where the sand is washed away, a deposite of clay is exposed; white, or whitish in the southeastern part of the state; but bluish on Connecticut river. This is the other variety of tertiary soils. Either of them in a pure state is exceedingly barren; but duly mixed, they form a very productive soil.

The sandstone soil is confined exclusively to the vicinity of Connecticut river. Most of the sandstone there is of a red color; some of it even a blood red; and its disintegration has produced a soil of the same aspect; so that even at a great distance, the redness is quite manifest. There is no soil that can easily be confounded with this, except some limited tracts of ferruginous gneiss soil in Worcester county, and of chocolate colored graywacke, and red compact feldspar, in the eastern part of the State. In a few towns, as in Granby, the sandstone soil is of a gray color, because the rock is gray beneath it.

The graywacke soil is confined to the eastern part of the State. Its color is mostly a deep brown; and it is capable of being made some of the best land in the State; as will be evident when I refer to Dorchester, Roxbury, Brookline, Newton, Cambridge, the Bridgewaters, Taunton, Middleborough, Dighton, Somerset, &c. for examples of its most perfect developement. In some of these towns the rock is chiefly a coarse conglomerate or plum pudding

stone; and as this contains more calcareous matter than the slaty varieties, and decomposes more readily, probably it furnishes the best soil found over this formation. The slaty varieties occur in Quincy, Newton, Charlestown, &c. In the southwest part of Attleborough, the slate is of a chocolate color, and this peculiar hue is imparted to the soil. The same color prevails in some other places; but not extensively enough to produce any striking patches of this variety of soil.

The tracts are very limited in Massachusetts, where well characterized argillaceous or roofing slate is fully developed: and hence we have but little genuine clay slate soil. Where it does occur, as in a few towns in Worcester and Middlesex counties, also in Bernardston, in Franklin county, it has the dark color of the slate; and is easily distinguished. It is capable of being made an excellent soil.

The limestone soil is confined to the county of Berkshire. I give it this name because it lies above limestone; not because it contains more of the salts of lime than other soils in the State. For to my surprise, I find that in general it does not. Much of it probably resulted from the disintegration of the mica and talcose slates that occur in large quantities along with the limestone in that county; and probably, also, the calcareous matter, which it did once contain, has been exhausted by cultivation. The magnesian limestone and the soil thence resulting, appeared to me more extensive (though not as pure) in New Marlborough than in any other part of the county.

The mica slate soil, which occupies extensive regions in Massachusetts, as the Geological Map will show, is distinguished in appearance from the clay slate soil, chiefly by being of a lighter color. Yet since the two rocks pass into each other imperceptibly, so do these soils. And in the western part of Berkshire county, as well as in the mica slate region, extending from Worcester to the mouth of Merrimack river, the mica slate approaches so near to argillaceous slate, that the soil above it might, without much error, be referred to the latter rock. Most of our mica slate soils are of a superior quality.

The talcose slate soil is rather limited, and not of the best quality: though it should be recollected that it occupies some of the highest parts of the State, and might at a lower level be more productive. It probably, however, contains too much magnesia. The argillo-tal-

cose slate soils of the west part of Berkshire, are of a better quality. In appearance the mica slate and talcose slate soils can hardly be distinguished from each other; though in general the latter is of a lighter color and more sandy.

Gneiss soil occupies more surface than any other in the State: and were we to judge from its appearance, we should conclude it the poorest soil within our limits. In general, it is of a pale yellow color, and very sandy or gravelly. And, indeed, in many places it is very meagre and unproductive. But over a great part of Worcester county, for instance, it is of a very different character, being enriched probably by the potassa of the feldspar and mica in gneiss. The ferruginous gneiss soil contains so much peroxide of iron, that in some towns, as West Brookfield, Sturbridge, Brimfield, Oakham, &c., it is of a perceptible red color when seen at a distance.

Since granite and gneiss are composed of the same ingredients, the soils which they produce will not differ. And in fact they do not in Massachusetts: so that probably there is little advantage in separating them.

Sienite differs from granite in taking hornblende into its composition, as well as being in general of a finer texture. The soil resulting from its decomposition is certainly more favorable to cultivation than that derived from common granite: as an example of which I may refer to nearly the whole of Essex county.

The compact feldspar, that forms the basis of porphyry, frequently contains an unusually large proportion of alumina, from 15 to 30 per cent. And although this is the hardest of the rocks around Boston, in many places it decomposes rapidly, and the resulting soil admits of high cultivation, as may be seen in Medford and Lynn.

The greenstone in the eastern part of the State is so intimately connected with sienite and porphyry, that the attempt to separate the soils resulting from them, is almost useless. Yet the structure of the greenstone is finer, and where it predominates, we find a good soil; as in Ipswich and Woburn. The greenstone associated with sandstone, near Connecticut river, has a more earthy aspect, and produces by decomposition a peculiar yet valuable soil, of a deep brown color, and abounding in iron. It is, however, but of limited extent.

Manner of collecting specimens of the Soils.

Having adopted this arrangement of our soils, it occurred to me that the proper way to make a collection of them for analysis would be to go upon each formation, and obtain specimens from different parts of it especially where the characteristics of the soil were most clearly developed. As it was not my object to examine the soil of any particular farm, I did not even inquire from whose land I obtained the specimen: but took it where I thought the particular soil that prevailed in the vicinity was most fairly exhibited, taking care, however, to obtain specimens from every important part of the different rock formations. In nearly every instance (the few excepted cases are noticed in the results that will soon be given) I took the soil from a cultivated ploughed field; and where it was possible, from land that had been ploughed long enough for the vegetable fibres to disappear. I avoided, whenever possible, the vicinity of buildings; and especially barn yards; as I did also fields that through neglect had become very poor. As I collected these specimens in the latter part of summer, and early part of autumn, I could judge by the crops where the cultivation had been good, but not extra. I wished to avoid, on the one hand, soil that had been very much exhausted; and, on the other, that which had become quite factitious by the application of various manures and in great quantity; because I supposed a medium state of cultivation would best exhibit the real capabilities of our soils. I took the specimen three or four inches below the surface, or about half way between the surface and the sub-soil;—avoiding, as much as possible, roots, undecayed manure, and large pebbles. And in my analysis, I separated with a very coarse sieve, all the pebbles, roots, &c. larger than the tenth of an inch in diameter; and of these I made no account. For although pebbles and fragments of undecayed vegetable matters exert some influence upon cultivation, and if in large quantity may essentially modify it, yet I do not believe that a chemical examination of these matters can add any thing to what the farmer already knows on this subject.

Mode of preparing and preserving the Specimens.

The specimens as they were collected were put into tin canisters, and labelled on the spot. Afterwards they were spread upon boards and exposed for several days to a very dry air and warm sun in October. Then they were returned to the canisters. Not long after the part not used for analysis was put into white glass bottles, which were numbered and sealed. This arrangement renders them easy to be examined by the eye without the danger of being wasted by uncorking them. These bottles, to the number of 125, along with 50 others, containing marls, clays, muck sand, marsh mud, ochres, &c. with several specimens of limestones, coal, ores, &c. not previously in the State collection, are deposited in the Rooms of the Boston Natural History Society, where they can be examined by the government.

Methods of analysing Soils.

The soils being thus got in readiness for analysis, an important and difficult question arose as to the best mode of conducting that operation. The three leading objects to be attained, by such an analysis, are, first to ascertain the nature and amount of the earths that form the basis of the soils. Secondly, the nature and amount of the salts that act as stimulants to vegetation; and thirdly, to determine the amount and condition of the organic matter which constitutes the nourishment of plants. Now to accomplish all these objects, by the most accurate methods of modern analysis, is a work of so great difficulty and labor, that the time which was at my disposal between the period of collecting the soils and the meeting of the Legislature, would not have been more than sufficient to have performed it upon half a dozen specimens. Indeed, every mode of analysis that has yet been proposed, leaves many important inquiries relating to the organic matter of soils untouched and unanswered. The method proposed by Sir Humphrey Davy has long been thought the best for practical purposes; and before making trial of it, I had the same opinion: and had it answered the purpose, I was confident I should be able in a few months to apply it to all the soils I had collected. But even though the results

should be such as that distinguished chemist represented: they would furnish only a very meagre account of a soil. Yet some parts of his process furnish only a very distant and uncertain approximation to the truth, as will be more fully shown further on. And it is not easy to understand how his method has been so long in such favor with almost all writers on the subject, except by supposing, that the real chemist has always seen it to be so inadequate that he has resorted to other modes when a soil was to be examined, while it is so complex and difficult that no agriculturist, who was not acquainted with chemical manipulation, and who had not access to a laboratory, has ever attempted to follow it: so that in fact, while all have recommended his rules, none have applied them. The difficulty was not that Sir Humphrey Davy did not understand all that was known on the subject when he wrote; but that in endeavoring to frame popular rules without compromitting his favorite science, he failed of his object. Still his rules do furnish results of some importance, and as I knew of no better ones which could be applied to a great number of soils within a short time, I selected a number of specimens of the different varieties of our soils, and examined them by his method considerably modified; and shall now proceed to bring the results together and inquire whether they teach any useful lesson. I should have proceeded farther in these examinations, had not a new and ingenious method of analysis been unexpectedly brought to my notice, which appeared to me much more important and satisfactory.

I ought to say, before giving the results above spoken of, that although I should not offer them if I did not suppose them accurate enough for all practical purposes, yet I do not suppose them to possess the precision that most modern analyses attain when skilfully conducted. For I was obliged to conduct a great number of these analyses together; and of course could not employ silver and platinum crucibles: nor has time been allowed me to verify the results by repeating the processes, as ought always to be done before scientific accuracy can be ensured. And the same remarks will apply, to some extent, to those other analyses which I shall present in this report: For although in all cases where it was necessary, the regular methods were employed by fusion with alkalis in silver or platinum vessels, yet no chemist who learns how numerous these analyses are, can believe it possible that they have been performed in the space of three

or four months with the repetitions necessary to ensure perfect accuracy. I would gladly have made these verifications: but I have done what I could; and that work, if ever accomplished, must be future. For the alternative was before me, either to quit my laboratory, or to disappoint the expectations of government, that I should make this report during the present session of the Legislature.

Examination for Calcareous Matter in our Soils.

A preliminary step of great importance in this analysis, consisted in an examination of the soils to ascertain whether they contain lime in the state of a carbonate;—that is, common limestone. And I conducted the process in the following manner. A small quantity of the soil was introduced into a watch glass, so placed that the light from a window would fall upon it. This soil was covered with water to a considerable depth. The soil was then stirred until all the light matter and every bubble of air had risen to the top. The impurity that floated on the surface was then removed by drawing over it a piece of bibulous paper, so that the water stood perfectly clear above the soil. Then a few drops of muriatic acid were added by a dropping tube, and the water was carefully watched to see if any bubbles rose through it, as they would have done if any carbonate were present. The minutest quantity of gas escaping, could in this manner be perceived. The result disclosed the remarkable fact, that *out of one hundred and twenty-five specimens of soils from all parts of the State, and several of them from limestone tracts, only seven exhibited any effervescence;* and even these, when analysed, yielded but a very small per cent of carbonate of lime, viz:

No. 31.	Graywacke soil,	Watertown,	1.3	per cent
— 51.	Limestone soil,	Sheffield,	0.8	"
— 52.	Do.	West Stockbridge,	3.2	"
— 78.	Gneiss soil,	Westminster,	3.0	"
— 80.	Do.	Fitchburg,	2.1	"
— 113.	Sienite soil,	Wrentham,	0.4	"
— 125.	Greenstone soil,	Deerfield,	2.0	"

Even in three of the above cases, Nos. 78, 80 and 125, I am strongly suspicious, that the calcareous matter might not have been natural to the soils. For, contrary to my usual custom, in these

cases I took the specimens from small patches of cultivated ground near villages; and very likely these spots might have been manured with sea shells, or lime in some other form. Setting these aside, *only one in thirty of our soils contains any calcareous matter.* This is so different from the account given in the books of European soils, that it will doubtless be very surprising. For some of these contain more than 50 per cent of this substance; and nearly all of them a large per cent. But in our country the lack of calcareous matter is not confined to Massachusetts. In the able work of Edmund Ruffin, Esq. of Virginia, on calcareous manures, a similar statement is made respecting the soils of that State, and of some of the Western States, even in limestone regions. I have, also, recently examined five of some of the richest soils of Ohio and Illinois, and although I find calcareous matter in all but one, yet the average quantity is not over two per cent. Hence I apprehend that we shall find a deficiency of carbonate of lime to be quite characteristic of a large part of the soils of this country. This could not always have been the case, especially in limestone regions, and hence we learn—what indeed agricultural chemists now generally admit—that in cultivated fields, calcareous matter is gradually changed or consumed: and hence too we learn, what is one of the great desiderata of the soils of Massachusetts. But more of this farther on.

Results of the first mode of Analysis.

For convenience of comparison, the analyses in the following table, and indeed all that I shall give in this Report, are reduced to the same standard, viz. 100 grains; although the quantities used were sometimes more and often less. In most cases there was a loss of several grains of the soil analysed. But as I make no pretensions to great accuracy in the following results, I have thought it would prevent needless embarrassment to proportion the loss among the several ingredients of the soil.

No.	NAME AND LOCALITY OF THE SOIL.	Water of Absorption.	Organic Matter.	Siliceous Deposite from Water.	Aluminous Deposite from Water.	Salts soluble in Water.	Composition of the Aluminous Deposite.				
							Silica by Acid.	Alumina by Acid.	Alumina by Hypothesis.	Silica by Hypothesis.	Oxide of Iron.
1	Alluvial Soil; Deerfield.	3.0	5.5	29.8	61.7		55.2	3.5	18.2	40.5	3.0
2	do Northampton.	3.4	5.1	32.8	58.5	0.20	51.7	3.4	17.6	37.5	3.4
3	do Deerfield.	2.0	4.5	43 2	50.3		44.1	3.7	14 8	33.0	2 5
4	do Northampton.	3.0	3.0	74.8	19.0	0.15	16.2	1.3	5.4	12.1	1.5
5	do Northfield.	2.7	4.2	43 9	49.2		44.0	2.4	14.3	32.1	2.8
6	do Northampton.	2.1	3.2	40.0	54.7		51.0	1.7	16.3	36.4	2.0
7	do West Springfield.	1.3	5.0	67.9	25.4	0.20	21.6	1.2	7.0	15.8	2.6
8	do Stockbridge.	1.9	4 9	83.5	9.7		7.4	1.3	2.7	6 0	1.0
9	do Hadley.	4.4	6 6	45.6	43.0	0 20	39.4	1.6	12.6	28.4	2.0
10	do Sheffield.	2.2	5.5	62.1	30.0	0.20	23 9	3.0	8.3	18.6	3 1
13	Tertiary Soil, Argillaceous; Springfield.	3.3	10.0	47.8	38.7	0.16	32.7	3.5	11.2	25 0	2.5
16	do do Barnstable.	2.6	9.4	47.2	40 8	0.05	29.8	6.7	11.3	25.2	4.3
18	do Sandy; Wareham.	1.2	0.4	98.4	0.0						
19	do do Springfield.	1.7	2.7	92.8	4 8		2.4	1.3	1.1	2.6	1.1
20	do do Barnstable.	1.0	0.2	98 3	0.5				0.15	0.35	
21	do do Gloucester, (Squam.)	0.15	0.0	99.6	0.0	0.20					
23	Sandstone Soil, red; Longmeadow.	2.4	4.4	79.0	14.0	0.20	10 6	1.3	3.7	8.2	2.1
25	do do West Springfield.	2 6	6.1	50.5	40 4	0.38	32 6	4.2	11.4	25.4	3.6
26	do grey; Granby.	2.8	3.9	37.3	55.9	0.13	48.6	2.6	15.9	35.3	4.7
27	Graywacke Soil, Conglomerate; Dorchester.	3 0	7 8	61.7	27.5		19.3	4.7	7.4	16 6	3.5
30	do do Walpole.	2.2	7.6	56 0	34.1	0.10	28.5	3.1	9.8	21 8	2.5
31	do do Dighton.	1.6	5.2	59 3	33.8	0.10					
32	do Slaty; Middleborough.	1.7	6.0	69 2	23.0	0 10	17 0	2.2	6.0	13.2	3.8
35	do do Watertown.	4.1	9.1	45 6	41.0	0 20	31.9	4.1	11.1	24 9	5.0
36	do do Halifax.	1.5	5.5	82.6	10.3	0.14	6 9	2.3	2 8	6.4	1.1
38	do do Taunton.	2.0	6.0	76 4	15 5	0.10	11.1	2.8	4.3	9.6	1.6
40	do do, red; Attleboro', S. W. part.	3.2	9.7	43.0	44.0	0.12	27.5	8.0	11.8	23.7	8.5

41	Argillaceous Slate Soil; Lancaster.	3.0	9.5	59.3	28.1	0.09	23.1	3.1	9.4	16.8	1.9
43	do do Townsend.	3.5	11.5	70.5	14.2	0.32	7.2	4.5	3.6	8.1	2.5
44	Limestone Soil, Magnesian; New Marlborough.	1.9	5.8	67.6	24.6	0.12	16.6	4.0	6.4	14.2	4.0
45	do common; Lanesborough,	2.5	7.5	61.3	28.5	0.20	17.0	4.5	6.6	14.9	7.0
47	do do North Adams.	1.4	5.1	73.9	19.5	0.14	13.5	3.5	6.3	10.7	2.5
50	do do Pittsfield.	4.0	9.0	63.7	23.2	0.10	16.2	4.0	6.3	13.9	3.0
51	do do Sheffield.	3.9	7.2	67.7	20.9	0.32	11.9	5.0	4.2	12.7	4.0
54	Mica Slate Soil; Webster.	2.8	10.4	51.2	35.5	0.14	27.9	5.4	10.3	23.0	2.2
56	do Stockbridge mountain.	3.1	7.4	59.7	29.7	0.10	19.7	4.7	7.5	16.9	5.3
58	do Bradford.	3.0	10.4	44.0	42.3	0.25	32.3	5.8	12.2	25.9	4.2
59	do West Newbury.	3.0	7.6	65.2	24.1	0.10	16.2	5.1	6.6	14.7	2.8
60	do Methuen.	1.4	4.0	83.0	11.6		6.4	1.0	2.3	5.1	4.2
63	do Conway.	1.4	6.3	67.7	24.5	0.10	18.3	4.3	8.5	14.1	1.9
65	Talcose Slate; Charlemont.	2.5	6.0	72.0	19.4	0.08	12.7	1.9	4.5	10.1	4.8
67	Talco-micaceous Slate Soil; Hancock.	2.8	9.7	44.8	42.7		30.4	7.6	11.8	26.2	4.7
70	Gneiss Soil; Bolton.	2.8	7.3	63.5	26.2	0.25	22.2	2.3	7.6	16.9	1.7
71	do Uxbridge.	2.5	7.0	37.8	52.5	0.19	44.8	4.3	15.2	33.9	3.4
77	do Rutland.	3.8	10.2	58.7	27.0	0.26	21.0	3.5	7.6	16.9	2.5
79	do Royalston.	4.0	9.0	67.6	19.3	0.14	14.9	3.2	5.6	12.5	1.2
89	do Grafton.	3.0	7.7	40.1	49.0	0.20	38.9	6.7	14.9	30.7	3.4
90	do Brimfield.	2.1	6.9	70.9	20.0	0.10	15.9	2.9	5.8	13.0	1.2
93	do Becket.	4.0	9.0	64.6	22.0	0.40	16.6	3.4	6.2	13.8	2.0
96	do Sturbridge.	1.8	5.7	77.1	15.2	0.22	11.3	2.3	9.4	4.2	1.6
104	Granite Soil; Andover.	3.3	9.5	54.4	32.6	0.20	26.9	3.9	9.5	21.3	1.8
106	Sienite Soil; Marblehead.	3.7	8.9	61.5	25.8	0.10	20.0	2.3	6.9	15.4	3.5
108	do Gloucester.	1.7	4.8	80.0	13.4	0.13	9.6	2.1	3.6	8.1	1.7
109	do Lexington.	3.7	10.0	46.7	39.4	0.16	34.0	3.0	11.5	25.5	2.4
111	do Newbury.	3.5	7.5	60.1	28.8	0.12	22.2	4.4	8.2	18.4	2.2
112	do Dedham.	4.3	9.9	46.3	39.3	0.17	31.4	5.1	13.5	23.0	2.8
117	do Marshfield.	2.0	5.2	68.7	24.0	0.11	19.2	2.7	6.8	15.1	2.1
120	Porphyry Soil; Medford.	4.1	10.6	51.9	33.2	0.15	27.7	3.5	9.6	21.6	2.0
122	do Lynn.	4.0	8.5	46.4	40.8	0.30	31.6	3.7	11.8	26.5	2.5
124	Greenstone Soil; Woburn.	4.0	10.3	46.7	38.9	0.15	33.7	2.3	11.1	24.9	2.9
125	do Deerfield.	2.0	7.0	32.7	58.2	0.10	50.5	3.3	16.6	37.2	4.4

Explanation of the preceding Table with Remarks.

The numbers in the first column of the preceding table, denote the specimens of the soils deposited in the State collection: and the second column points out the name and locality.

However thoroughly soils are dried in the sun, a quantity of water still adheres to them, which cannot be entirely driven off, until they are heated to nearly 300° of Fahrenheit's thermometer; or to the point where paper begins to turn brown. This was the way in which the numbers in the third column were obtained, by heating 100 grains to that point and noting the loss of weight. Highly siliceous soils retain but very little of this water of absorption, while from highly aluminous ones, it is not all driven off by heating to 300°. The power of soils to retain water, however, depends much more upon the quantity and character of the organic matter which they contain, than upon their mineral composition, as I shall endeavor to show hereafter.

After driving off the water of absorption, the soil was heated to redness, and continued in that state until every thing combustible was burnt off. The loss of weight showed the quantity of organic matter; and thus the fourth column was formed.

Thus, if we follow the ordinary rules, we get rid at once of the most complicated and valuable part of soils, viz. the nourishment which they contain for sustaining vegetation: and in this respect the common modes of analysis are probably the most deficient. True, in this way, we get the quantity of vegetable and animal matter which a soil contains. But every farmer knows that his land may abound in such matter, and yet be almost entirely unproductive: as for instance, if it be filled with unchanged peaty matter from the swamps. He also knows that a field may contain but little organic matter, and yet be very productive, although soon exhausted. He knows, likewise, that the same quantity of manure on different fields will render the soil productive on some of them much longer than on others. Hence we learn that the most important point in this part of analysis is to determine in what state the organic matter is; whether in such a condition that it will at once afford nourishment to

vegetation, or not until it has undergone a chemical change; and whether it is in such a state as to be liable to be dissipated by the common action of moisture, heat, and cold; or so fixed as to be permanent. Yet the methods of analysis given in the books, furnish no rules for deciding these points. This deficiency however, in my opinion, has been at length supplied by a chemical friend, and will be exhibited in the sequel.

The fourth column in the above table presents one fact worthy of notice. It seems that our alluvial soils, although deservedly celebrated, contain less of organic matter than almost any other in the State. The principles above suggested explain their fertility in consistency with this fact: but it shows us, if I mistake not, that such soils, if not constantly supplied with manures, either by the overflowing of rivers, or by the farmer, will be sooner exhausted than almost any others.

The numbers in the fifth and sixth columns were obtained in the following manner. One hundred grains of the soil were boiled a short time in a glass flask in water, and after cooling, this was agitated until the soil was all diffused through the water. As soon as the agitation of the water had ceased, it was poured off along with the finer parts of the soil that did not settle at once. The portion that remained usually consisted of siliceous sand, while that which was left suspended in the water, was much more aluminous, and constituted the finer and most important part of the soil. In the present instance, this deposite is in larger proportion than is usual in analysis, because it was poured off immediately after the agitation had ceased, under an impression that by waiting two or three minutes, as is usual, other and more important substances than silica may settle to the bottom of the vessel. Indeed, I found this to be the case in some instances when the light matter was poured off immediately. Thus, the red sandstone soil, No. 23, from Longmeadow, gave only 14 grains of aluminous matter, and 79 grains of siliceous. By digestion in acid, the 14 grains yielded only 1.3 gr. of alumina and 2.1 gr. oxide of iron. But by treating the 79 grains of siliceous matter in the same way, it produced 7.5 grains of alumina and 4 grains peroxide of iron. Such cases teach us that this mechanical separation of the siliceous and aluminous matter is not a little uncer-

tain: although in general it must be confessed, that when the lighter part was poured off immediately, the remainder was chiefly siliceous sand.

It is not the object of this process however, to show us the quantity of silica and alumina in a soil: but rather the amount of finely divided matter. For the best soils are found, in general, to abound in such matter: although it may become excessive, rendering the soil impervious to air and moisture. This is a principal defect in highly argillaceous soils. But from the preceding table it appears, in my opinion, that the soils in Massachusetts are in general too coarse rather than too fine. Being derived chiefly from primitive rocks, they resist comminution and decomposition more than the secondary rocks. I am satisfied that the principal excellence of our alluvial soils depends more upon their finely divided state than any thing else: for, as I have already in part shown, and shall show farther in the sequel, they must yield in value in some important respects, to our upland soils. And even as to their fineness, they are much coarser than many of the rich alluvia of the Western States; though it may be doubted whether for most crops they are on this account the less valuable.

The term salt, in chemistry, has a much more extended meaning than in popular language. Thus common limestone (carbonate of lime) and gypsum (sulphate of lime) are properly denominated salts, as is also phosphate of lime and chloride of calcium (muriate of lime). All compounds of any acid with lime, magnesia, alumina, potassa, soda, &c. or of chlorine with their metallic basis are salts: and some of these are soluble and some insoluble in water. If any of the former exist in soils therefore, they will be dissolved, if the soil be boiled in water. And if afterwards this water be evaporated, the salt can be obtained in a dry state and weighed. This is the way in which column seventh was filled. Tests were also applied to the solutions, in order to ascertain the nature of these salts. Hydrocyanate of potassa, infusion of nutgalls, the chlorides of calcium and magnesium, and the carbonate of ammonia and phosphate of soda gave no precipitate in any instance. Hence I infer the absence of iron and the salts of magnesia. But nitrate of silver, baryta water,

nitrate and acetate of baryta, and oxalate of ammonia, gave precipitates more or less abundant in every instance in which I tried them. I hence infer the presence of a sulphate, probably the sulphate of lime, in all the soils of Massachusetts that I have examined, and I have no doubt but it exists in every one of our soils. The quantity given in the table, is probably much less than the truth, for the sulphate of lime is but slightly soluble in water, and the quantity of water which I employed, was too small to dissolve all that exists in 100 grains; or rather 200 grains, which was the quantity usually boiled. It was chiefly to ascertain the fact of its existence that the experiments were performed; since I had adopted a better methed for ascertaining its quantity. This salt exists, also, probably in nearly all the springs, rivers, and ponds in the state. The great importance of gypsum, in the process of vegetation, furnishes a reason for its universal diffusion.

The four remaining columns of the table exhibit the composition of the aluminous deposite in the sixth column. That deposite was boiled two or three hours in sulphuric, or hydrochloric acid, and the alumina and iron were precipitated together by carbonate of ammonia, and afterwards separated by hydrate of potassa. The portion remaining undissolved by the acid, was considered as silica. This separation of alumina and iron by boiling in acid, is the method directed by Sir Humphrey Davy; yet it is entirely insufficient. The greater part of the iron is probably thus separated; but not so the alumina. Not half of this is generally taken up by the acid. The true and effectual way of doing this is by fusion with a carbonated alkali, in a platinum crucible. In this way, in a few instances, I treated the silica that remained after the action of the acid, and obtained the following results. The second column contains the aluminous deposite from water to be examined; the third, the alumina separated by boiling in acid, as in the table; the fourth, the alumina obtained by the process with carbonate of soda, added to that by acids; the fifth, the remaining silica after the action of acids; the sixth, the silica obtained by the alkali; and the last, the per cent of alumina in the aluminous deposite.

No.	Aluminous Deposite.	Alumina by Acids.	Alumina by Alkali.	Silica by Acids.	Silica by Alkali.	Alumina per cent.	
2	58.5	3.4	17.6	51.0	37.5	30.1	
40	44.0	8.0	11.8	27.5	23.7	26.8	
41	28.1	3.1	9.4	23.1	16.8	33.6	
47	19.5	3.5	6.3	13.5	10.7	32.3	30.9 Mean.
58	42.3	5.8	12.2	32.3	25.9	28.8	
89	49.0	6.7	14.9	38.9	30.7	30.4	
112	39.3	5.1	13.	31.3	23.0	34.3	

The small differences in the last column of the above table, between the alumina per cent, in the different specimens, suggested the idea, that by taking the mean result as a standard, an approximate estimate of the real quantity of alumina and silica, in all the aluminous deposites given in the general table, might be obtained, by simply multiplying those deposites, after subtracting the amount of iron, by that mean. In this way were the tenth and eleventh columns of the general table obtained. I have little doubt but they give the amount of alumina and silica in the finer part of the soils, within a few per cent, and accurately enough for all the common purposes of agriculture; although this is not a very scientific way of obtaining the results. Nor should I have adopted it, had time permitted me to analyse all the specimens by alkali, in the dry way,—the only way that will satisfy the chemist. By the time I had proceeded thus far in the analysis which I am describing, I became quite convinced that to obtain the exact quantity of silica and alumina in a soil, is a matter of very little importance in an agricultural point of view. I know that a soil consisting wholly of one kind of earth, will be barren; yet if a soil be finely divided it may consist mostly of one sort of earth, and yet, by proper cultivation, be rendered fertile. The proportions of silica and alumina may vary widely, and yet the power of producing plants remain essentially the same. And even where a soil is extremely siliceous or aluminous, some modifications in the mode of treating it will make it fertile. It hardly needs a chemical analysis to teach us when a soil is siliceous or aluminous.

I am satisfied, however, that the agency of the oxides of iron in agriculture has been underrated, and that a determination of the precise quantity of this substance which exists in all our soils, may be important.

These views are confirmed by the opinion of gentlemen distinguished for their accurate and practical acquaintance with chemistry. I will quote here only the opinion of A. A. Hayes, Esq., of Roxbury, as I shall soon have occasion to present, in another connection, the views of another gentleman, which, as well as those of Mr Hayes, will always command great respect. The latter, speaking of the earthy composition of soils in general, says, "I do not think that minute analyses of the earthy constituents of soils, have the valuable practical bearing which careful comparative results possess. With a fondness for observing influences, considered as minute, I should hesitate, with even such a bias, to attribute to chemical composition, so far as the earths are concerned, observed qualities in soils of great importance to cultivation; and am now strongly of the opinion, that those examinations which you propose making, will not only show our farmers the light of new knowledge, but confer on them a practical benefit, in teaching the proper modes of improving soils."*

In examining the table of analyses, above presented, it should be recollected, that the amount of alumina given, is only that which exists in the finely divided portion of the soil that remained suspended in water after agitation. In a single case, which I have already stated, the siliceous residuum was found to contain more iron and alumina than the aluminous part. But this was a peculiar case; and in general, the siliceous deposite contains little but siliceous sand. Still, where it contains fragments of feldspar, mica, &c., analysis will produce alumina and iron, although they must be in such a state as to operate upon cultivation just like siliceous sand, until decomposition begins. I have made only a single analysis to determine the quantity of alumina and iron in 100 grains of the entire soil; viz. No. 15, a tertiary argillaceous soil from Plymouth. I should expect in this specimen that both these ingredients would be above the average quantity in the soils of the State. The following is the result.

* I trust Mr. Hayes will excuse the liberty I have here taken in quoting from a private letter.

Water of absorption	2.7
Organic matter	6.0
Oxide of iron	6.5
Salts soluble in water.	0.4
Alumina	19.2
Silica	65.2
	100

The degree of fineness in a soil is undoubtedly a matter of much importance: and fortunately the means of determining this point are within the reach of every farmer, in the manner already described. Since silica and alumina are quite inert in their properties, and enter but in small quantity into the composition of plants, it is probable that the one may to a great extent be substituted for the others without affecting the vegetation, provided they be reduced to the proper degree of fineness. On this point I am happy to quote a paragraph from Mr. Hayes, in which he gives his views of the process for alumina by Sir Humphrey Davy, which has been already described.

"The process of Sir Humphrey Davy for dissolving alumina in sulphuric acid," says he, "is by no means exact. It was his intention evidently, to dissolve in that agent, the alumina of any easily decomposable mineral existing in the finer parts of a soil; and in this application it is of value. Supposing we are operating on a white clay from Gay Head. Sulphuric acid, of the degree of 1.30, will dissolve at 60° F. a certain small portion of alumina and set free some hydrate of silica; traces of potash will also exist in the fluid. If the well washed residue, be boiled for two hours in like acid, another portion of alumina will be dissolved. By subsequently mixing the residue with concentrated sulphuric acid, and gradually heating the mass to 600° F. another quantity of the same base is taken up; and after water has removed all soluble matter the basic sulphate of alumina will, in a few weeks, cause the residue to effloresce. These effects are all referable to the state of aggregation of the particles, not only as regards fineness of powder, but permeability of structure. In soils it is probable that *the hydrates of the earths, as such, do not exist;* for we find always that a relatively electro-positive body appears when we dissolve them. As the influence of the earths is most important to

vegetation, in supplying the fluid favorable to its support, may not the greater or less degree of fineness of one of the constituents of a soil materially change its nature? The process of absorption and retention may be so much modified by comminution, that I think a silico-ferruginous soil may assume the characters of an aluminous soil to a certain extent, and that the existence of a due proportion of finely divided matter is of more consequence than is its composition."

But even though the quantity of the earthy constituents of a soil may vary considerably without affecting its fertility, yet this is by no means the case with its other constituents, the salts and organic matter. The salts especially, admit of but little variation without producing sterility, either by their deficiency or excess; and hence to determine their amount, is an important point in agricultural chemistry. And the differences which are so obvious in soils derived from different rocks, do not depend entirely upon the different proportions of the earths which they contain. For the quantity and nature of the salts resulting from the decomposition of rocks are considerably different. Thus, we should expect that the gneiss and granite soils would contain a larger amount than usual of the salts of potassa, and where sulphuret of iron prevails, of the salts of iron: the porphyry soils, of the salts of soda: the graywacke and sandstone soils, of the salts of lime, magnesia and perhaps potassa, and soda; the mica slate soils, of the salts of magnesia and potassa; the talcose slate soil, of the salts of magnesia: or perhaps more commonly we should find the lime and magnesia uncombined with an acid. Such differences as these in the constituents of soils, will unquestionably affect their fertility; and it would be desirable to ascertain how far they exist in the soils of Massachusetts. I had hoped to accomplish this object: but it will require a great number of delicate and accurate analyses, demanding far more time than has yet been allowed me. As will be seen in the sequel, I have attempted to determine the amount of the salts of lime in all the soils that I have collected; but it will need comparative trials by the ordinary modes of analysis, before the peculiar characteristics of the different classes of our soils can be pointed out; and besides, I have made no attempt to determine the existence and amount of potassa and soda in my specimens. In several of the analyses, whose results are given in the preceding general table, I determined the existence and amount of pure lime: but the

results appear to me of too little importance to give in detail; especially as I shall soon give, what I consider more important results of a similar character, obtained in another way. It is worth stating, however, that in all cases in which a test was applied to the solvent of the soils, it showed the presence of lime; though, as has been stated, very few specimens contained any of the carbonate of lime. In nearly every case, also, I found magnesia to be present. In the following instances I determined its amount, which, it will be seen, is small, and probably, therefore, of little consequence in an agricultural point of view.

No. 1.	Magnesia	per cent	0.66,	alluvial soil,	Deerfield.
2.	"	"	0.57	"	Northampton.
3.	"	"	0.01	"	Deerfield.
4.	"	"	0.01	"	Northampton.
5.	"	"	0.15	"	Northfield.
6.	"	"	0.15	"	Northampton.
7.	"	"	0.01	"	West Springfield.
8.	"	"	0.76	"	Stockbridge.
9.	"	"	0.01	"	Hadley.
10.	"	"	0.06	"	Sheffield.
44.	"	"	1.66	magnesian limestone soil,	New Marlborough.
50.	"	"	0.45	limestone do,	Pittsfield.
51.	"	"	0.76	"	Sheffield.
108.	"	"	0.02	sienite soil,	Gloucester.
109.	"	"	0.01	"	Lexington.
111.	"	"	0.05	"	Newbury.
112.	"	"	0.50	"	Dedham.
120.	"	"	0.05	porphyry soil,	Medford.
122.	"	"	0.05	"	Lynn.
124.	"	"	0.10	greenstone soil,	Woburn.
125.	"	"	0.40	"	Deerfield.

The last column in the general table of results contains the amount of peroxide of iron in the aluminous deposite of the soils. It is less than the quantity in the entire soil: because, although the siliceous part contains less than the aluminous, it is seldom if ever free from this metal. Upon the whole, the soils of Massachusetts contain a rather large per cent of iron.

As to the effect of oxide of iron upon vegetation, agricultural chemists seem in general to have formed no definite opinion: though the idea seems to be rather prevalent that it is generally deleterious. It is well known that iron exists in two states in rocks; that of the protoxide, and the peroxide; the latter containing more oxygen than the former. And Chaptal, the distinguished French chemist, thinks that some of his experiments prove, that the protoxide is decidedly injurious to vegetation. But from the fact that the green sand marl of New Jersey and Virginia, which is operating so favorably upon the lands of those States, contains a large proportion of protoxide of iron, Prof. William B. Rogers suggests whether its fertilizing effects may not proceed in part from the alkaline reaction of the protoxide. I shall soon present some facts and reasonings on this subject by another able chemist, which go to show, that iron, in passing into the state of peroxide, exerts a very favorable effect upon the nutriment in soils: and that when in the state of peroxide, its effect is good as a general fact. In general the iron in our soils is already peroxidized, though not always; and the agricultural character of most of our highly ferruginous soils, as for instance the reddish soils in the Brookfields, in Sturbridge, Brimfield, Wilbraham, Longmeadow, West Springfield, &c. confirms the opinion that iron, although it often gives a meagre aspect to the fields, is yet, in moderate quantities, of great service. This we might presume would be the case, from the fact that it is found in nearly all plants in considerable quantity, and also in every productive soil. As however this opinion will probably be controverted, it may not be irrelevant to say, that Massachusetts affords in many parts, fine opportunities for settling the question; and also for determining in what state and proportion iron is best adapted for agriculture.

New method of analysing Soils.

Without stopping to suggest any means for supplying the deficiencies which the preceding analyses have shown in our soils, I proceed to the developement of a new method of analysis, which I very unexpectedly received from a distinguished chemical friend, and which he has allowed me to present in this Report, with its application to our soils. It is the invention of Dr. Samuel L. Dana of Lowell; to

whom, as will appear in the sequel, I am indebted for other important assistance in the way of analysis. In order to its being fully understood and appreciated, a few preliminary statements from myself, in addition to those by Dr. Dana, will be necessary.

Till within a few years past, the state in which vegetable and animal matter exists in the soil, and the changes through which it passes, before being taken up by the roots of the plant, were almost entirely unknown to chemists. Long ago, however, Klaproth had discovered a peculiar substance in the elm tree, which he denominated *ulmin.* More recently it was found by Braconnot in starch, saw-dust, and sugar; and by the distinguished Swedish chemist, Berzelius, in all kinds of barks. Sprengel, and Polydore Boullay have ascertained, also, that it constitutes a leading principle in manures and soils. Hence they called it *Humin;* but Berzelius adopts the name of *Geine.* When wet, it is a gelatinous mass, which, on drying, becomes of a deep brown or almost black color, without taste or smell, and insoluble in water; and, therefore, in this state incapable of being absorbed by the roots of plants. Yet after the action of alkalis upon it, it assumes the character of an acid, and unites with ammonia, potassa, lime, alumina, &c., and forms a class of bodies called *Geates,* most of which are soluble in water, and therefore capable of being taken up by plants. And it is in the state of geates, that this substance for the most part exists in the soil. I have thought it might at least gratify curiosity and perhaps be of some practical use, to add specimens of these forms of geine to the collection of soils. No. 227 is pure geine: No. 226 geate of potassa: No. 225 geate of lime: No. 224 geate of alumina.

It is but justice to say, that Dr. Dana derived his knowledge of geine chiefly from his own researches, made with a view to improve the coloring processes in the Calico Printing Establishment, at Lowell: and his method of analysing soils is altogether original. The statements of Berzelius, indeed, though interesting in a theoretical point of view, afford very little light to the practical agriculturist. Those of Dr. Dana appear to me to be far more important in a scientific as well as practical point of view; although essentially coinciding with those European chemists, so far as they have gone. His method of analysis, derived from his researches, I must say, after having made extensive application of it to our soils, is simple and ele-

gant, and taken in connection with his preliminary remarks, it appears to me to be a most important contribution to agricultural chemistry, and promises much for the advancement of practical agriculture. I trust it will be favorably received by the government, and by all intelligent men, who take an interest in the subject. His preliminary remarks and rules I shall now present in his own language.

"By *geine*," says he, "I mean all the decomposed organic matter of the soil. It results chiefly from vegetable decomposition; animal substances produce a similar compound containing azote. There may be undecomposed vegetable fibre so minutely divided as to pass through the sieve; (see first step in the rules for analysis) but as one object of this operation is to free the soil from vegetable fibre, the portion will be quite inconsiderable. It can effect only the amount of insoluble geine. When so minutely divided, it will probably pass into geine in a season's cultivation. Geine exists in two states: soluble and insoluble: soluble both in water and in alkali, in alcohol and acids. The immediate result of recent decomposition of vegetable fibre is abundantly soluble in water. It is what is called, Solution of Vegetable Extract. Air converts this soluble into *solid* geine, *still partially soluble in water*, wholly soluble in alkali. Insoluble geine is the result of the decomposition of solid geine; but this insoluble geine, by the long continued action of air and moisture, is again so altered as to become soluble. It is speedily converted by the action of lime into soluble geine. Soluble geine acts neither as acid nor alkali. *It is converted into a substance having acid properties by the action of alkali*, and in this state combines with earths, alkalies, and oxides, forming neutral salts, which may be termed *geates*. These all are more soluble in water than solid geine; especially when they are first formed. Their solubility in cold water is as follows: beginning with the easiest, magnesia—lime—manganese—peroxide of iron—(it does not unite with the protoxide of iron) alumina—baryta. The geates of the alkaline earths are decomposed by carbonated alkali. The geates of alumina and of metallic oxides are soluble in caustic or carbonated alkali without decomposition. The geates of the alkaline earths, by the action of the carbonic acid of the air, become *super-geates*, always more soluble than neutral salts. Soluble geine, therefore includes the watery solution—the solid extract caus-

ed by the action of air on the solution, and the combinations of this with alkalies, earths, and oxides. Insoluable geine includes all the other forms of this substance."

"Soluble geine is the food of plants. Insoluble geine becomes food by air and moisture. Hence the reason and result of tillage. Hence the reason of employing pearlash to separate soluble and insoluble geine in analysis."

"These are the facts. Will they not lead us to a rational account of the use of lime, clay, ashes and spent ley? Will they not account for the superiority of unfermented over fermented dung in some cases?"

Dr. Dana's remarks in answer to these inquiries I shall omit for the present, and quote the remainder of his remarks preliminary to his rules for analysis. If any sentences seem to be somewhat repetitious of those already quoted, it is sufficient to say, that they were communicated at different times, in private letters, in answer to inquiries which I had made, that I might be sure not to mistake his meaning. On a subject so new, some repetitions are not undesirable.

"Geine forms the basis of all the nourishing part of all vegetable manures. The relations of soils to heat and moisture depend chiefly on geine. It is in fact, under its three states of 'vegetable extract, geine, and carbonaceous mould,' the principle which gives fertility to soils long after the action of common manures has ceased. In these three states it is essentially the same. The experiments of Saussure have long ago proved that air and moisture convert insoluble into soluble geine. Of all the problems to be solved by agricultural chemistry, none is of so great practical importance as the determination of the quantity of soluble and insoluble geine in soils. This is a question of much higher importance than the nature and proportions of the earthy constituents and soluble salts of soils. It lies at the foundation of all successful cultivation. Its importance has been not so much overlooked as undervalued. Hence, on this point the least light has been reflected from the labors of Davy and Chaptal. It needs but a glance at any analysis of soils, published in the books, to see that fertility depends not on the proportion of the earthy ingredients. Among the few facts, best established in chemical agriculture, are these: that a soil, whose earthy part is com-

posed wholly, or chiefly, of one earth; or any soil, with excess of salts, is always barren; and that plants grow equally well in all soils, destitute of *geine*, up to the period of fructification,—failing of geine, the fruit fails, the plants die. Earths, and salts, and geine, constitute, then, all that is essential; and soils will be fertile, in proportion as the last is mixed with the first. The earths are the plates, the salts the seasoning, the geine the food of plants. The salts can be varied but very little in their proportions, without injury. The earths admit of wide variety in their nature and proportions. I would resolve all into '*granitic sand;*' by which I mean the finely divided, almost impalpable mixture of the detritus of granite, gneiss, mica slate, sienite, and argillite; the last, giving by analysis, a compound very similar to the former. When we look at the analysis of vegetables, we find these inorganic principles constant constituents—silica, lime, magnesia, oxide of iron, potash, soda, and sulphuric and phosphoric acids. Hence these will be found constituents of all soils. The phosphats have been overlooked from the known difficulty of detecting phosphoric acid. Phosphate of lime is so easily soluble when combined with mucilage or gelatine, that it is among the first principles of soils exhausted. Doubtless the good effects, the lasting effects, of bone manure, depend more on the phosphat of lime, than on its animal portion. Though the same plants growing in different soils are found to yield variable quantities of the *salts* and earthy compounds; yet I believe, that accurate analysis will show, that similar parts of the same species, at the same age, always contain the inorganic principles above named, when grown in soils arising from the natural decomposition of granite rocks. These inorganic substances will be found not only in constant quantity, but always in definite proportion to the vegetable portion of each plant. The effect of cultivation may depend, therefore, much more on the introduction of *salts* than has been generally supposed. The *salts* introduce new breeds. So long as the salts and earths exist in the soil, so long will they form voltaic batteries with the roots of growing plants; by which, the 'granitic sand' is decomposed and the nascent earths, in this state readily soluble, are taken up by the absorbents of the roots, always a living, never a mechanical operation. Hence so long as the soil is *granitic*, using

the term as above defined, so long is it as good as on the day of its deposition; *salts* and *geine* may vary, and must be modified by cultivation. The universal diffusion of granitic diluvium will always afford enough of the earthy ingredients. The fertile character of soils, I presume, will not be found dependent on any particular rock formation on which it reposes. Modified they may be, to a certain extent, by peculiar formations; but all our granitic rocks afford, when decomposed, all those inorganic principles which plants demand. This is so true, that on this point the farmer already knows all that chemistry can teach him. Clay and sand, every one knows: a soil too sandy, too clayey, may be modified by mixture, but the best possible mixture does not give fertility. That depends on salts and geine. If these views are correct, the few properties of geine which I have mentioned, will lead us at once to a simple and accurate mode of analysing soils,—a mode, which determines at once the value of a soil, from its quantity of soluble and insoluble vegetable nutriment,—a mode, requiring no array of apparatus, nor delicate experimental tact,—one, which the country gentleman may apply with very great accuracy; and, with a little modification, perfectly within the reach of any man who can drive a team or hold a plough."

Rules of Analysis.

1. "Sift the soil through a fine sieve. Take the fine part; *bake* it just up to browning paper."

2. "Boil 100 grains of the baked soil, with 50 grains of pearl ashes, saleratus or carbonate of soda, in 4 ounces of water, for half an hour; let it settle; decant the clear; wash the grounds with 4 ounces boiling water; throw all on a weighed filter, previously dried at the same temperature as was the soil, (1); wash till colorless water returns. Mix all these liquors. It is a brown colored solution of all the soluble geine. All sulphats have been converted into carbonates, and with any phosphats, are on the filter. Dry therefore, that, with its contents, at the same heat as before. Weigh —the loss is *soluble geine*."

3. "If you wish to examine the geine; precipitate the alkaline solution with excess of lime-water. The *geate* of lime will rapidly

subside, and if lime-water enough has been added, the nitrous liquor will be colorless. Collect the geate of lime on a filter; wash with a little acetic or very dilute muriatic acid, and you have geine quite pure. Dry and weigh."

4. "Replace on a funnel the filter (2) and its earthy contents; wash with 2 drams muriatic acid, diluted with three times its bulk of cold water. Wash till tasteless. The carbonate and phosphate of lime will be dissolved with a little iron, which has resulted from the decomposition of any salts of iron, beside a little oxide of iron. The alumina will be scarcely touched. We may estimate all as *salts* of lime. Evaporate the muriatic solution to dryness, weigh and dissolve in boiling water. The insoluble will be *phosphat of lime.* Weigh—the loss is the *sulphate of lime;* (I make no allowance here for the difference in atomic weights of the acids, as the result is of no consequence in this analysis.)"

5. "The earthy residuum, if of a greyish white color, contains no insoluble geine—test it by burning a weighed small quantity on a hot shovel—if the odor of burning peat is given off, the presence of insoluble geine is indicated. If so, *calcine* the earthy residuum and its filter—the loss of weight will give the insoluble geine; that part which air and moisture, time and lime, will convert into soluble vegetable food. Any error here will be due to the loss of water in a hydrate, if one be present, but these exist in too small quantities in 'granitic sand,' to affect the result. The actual weight of the residuary mass is 'granitic sand.'

"The clay, mica, quartz, &c. are easily distinguished. If your soil is calcareous, which may be easily tested by acids; then before proceeding to this analysis, boil 100 grains in a pint of water, filter and dry as before, the loss of weight is due to the *sulphate of lime*, even the sulphate of iron may be so considered; for the ultimate result in cultivation is to convert this into sulphate of lime."

"Test the soil with muriatic acid, and having thus removed the lime, proceed as before, to determine the geine and insoluble vegetable matter."*

* In applying Dr. Dana's rules given in the text, to the soils of Massachusetts, I found it necessary to adopt some method of carrying forward several processes together. I accordingly made ten compartments upon a table, each provided with apparatus for filtering and

As soon as made acquainted with this mode of analysis it appeared to me so much more important and accurate than any other with which I was conversant, that I felt determined, if possible, to apply it to at least a part of the soils of Massachusetts; and by extra efforts, I have the pleasure of presenting in the following table the results of its application to all our soils which I have collected; and I shall show hereafter, similar results with our marls, clays, and other substances, to which this method can be applied.

It is proper to add, that the doctrines of Berzelius and other chemists respecting geine, have been strenuously opposed by M. F. V. Raspail, a French chemist, in his new system of Organic Chemistry, translated by Dr. Henderson, and published in London in 1834. He denies the existence of any such proximate principle in soils as geine, and says, "it will be easy to see that all these phenomena (described by Berzelius and others) apparently so varied, which have given room for the discovery of so many substances analogous in their nature to ulmin, are essentially nothing but a developement of carbon." To prove this position he enters into a long argument. This, however, did not convince Berzelius that he had committed an error; but he was led rather to express a still stronger conviction of the truth of his positions. It is not thought proper in this place to enter into this discussion. But it has occurred to me, that even if Raspail had shown that geine is nothing but carbon, it can hardly be doubted by any one who has made any experiments on the subject, that in all its forms of geine, geic acid, and geates, it is soluble to such an extent as to be capable of being taken up by the roots of plants; and if so it is not of much importance by what name it is called: nor will it affect essentially Dr. Dana's rules of analysis. Raspail, however, asserts that geine is never actually dissolved, but only suspended! Plants, he conceives, are nourished almost entirely by carbonic acid; and in following out his views on this point he is led to the strange conclusion—a legitimate one, however, from his pre-

precipitations, also 10 numbered flasks, 10 evaporating dishes, and a piece of sheet iron pierced with ten holes, for receiving the same number of crucibles. I provided, also, a sheet iron oven, with a tin bottom large enough to admit 10 filters, arranged in proper order, and a hole in the top to admit a thermometer. The sand bath was also made large enough for receiving the ten flasks In this manner I was able to conduct ten processes with almost as great facility as one could have been carried forward in the usual way.

mises and no small proof that they are erroneous—that, "possibly, by artificially supplying to the plant, the carbonic acid which is necessary to its growth, the use of any kind of manure may be dispensed with! In fact, if a small plant be reared in pure sand, taking care to water it frequently, it will thrive and flower without difficulty." As to the truth of this statement, here made, this writer will probably find but few chemists at this day who will agree with him. They will doubt whether, in all such cases, the "pure sand" or the water employed has not contained minute quantities of the substances found in the plant, which neither pure water nor pure silica can supply. Or if they admit that the plant might be made to grow till the time of flowering in pure sand; they will deny that it can be made to produce fruit without the presence of geine. At any rate until carbonic acid can be artificially supplied to plants, which even Raspail would not suppose can ever be done on such a scale as to supersede the necessity of manures, decomposed organic matter must be essential in cultivation; and to ascertain the amount and condition of this, is one great object of Dr. Dana's rules of analysis: nor will their value be the less, because chemists are not entirely agreed as to the nature of the nutritive principle, and because we have some things yet to learn respecting geine.*

* Some valuable and interesting statements respecting geine, may be found in the "Penny Cyclopedia," Article, *Arable Land*; also in the Edinburgh Quarterly Journal of Agriculture.

Number.	Name and Locality of the Soil.	Soluble Geine.	Insoluble Geine.	Salts of Lime. Sulphate.	Salts of Lime. Carbonate.	Salts of Lime. Phosphate.	Granitic Sand.	100 grains heated to 300° F. absorbed in 24 hours.	Absorbing Power in Proportional Numbers.	Specific Gravity.
1	Alluvium—Deerfield,	3.5	1.2	2.0		0.9	92.4	3.3	65	2.44
2	do Northampton,	2.8	4.2	2.4		1.0	89.6	2.0	40	2.45
3	do Deerfield,	2.3	1.1	1.6		0.9	94.1	2.1	42	2.58
4	do Northampton,	1.2	2.4	0.9		1.1	94.4	1.2	25	2.68
5	do Northfield,	2.8	2.8	1.5		0.6	92.3	2.9	58	2.55
6	do Northampton,	2.4	0.8	2.8		0.8	93.2	1.4	28	2.55
7	do W. Springfield,	3.2	1.2	1.3		0.7	93.6	3.0	60	2.46
8	do Stockbridge,	3.3	0.8	2.9		0.5	92.5	1.9	38	2.55
9	do Hadley,	2.5	2.3	2.7		1.0	91.5	5.0	100	2.46
10	do Sheffield,	1.3	5.2	1.7		0.5	91.3	3.5	70	2.53
11	do Deerfield,	2.5	2.4	0.8		0.8	93.5	2.0	40	2.58
12	do W. Springfield,	1.5	1.5	1.0		0.5	95.5	1.5	30	2.65
13	Tertiary Argillaceous—Springfield,	4.8	5.8	2.4		1.2	85.8	6.3	126	2.31
14	do Northampton,	4.8	4.6	1.6		0.8	88.2	6.1	122	2.37
15	do Plymouth,	2.9	4.9	1.8		0.9	89.5	4.9	98	2.34
16	do Barnstable,	4.4	5.9	0.9		0.6	88.2	4.9	98	2.39
17	do Sandwich,	2.8	4.9	3.0		1.1	88.2	4.2	84	2.37
18	Tertiary, Sandy—Wareham,	0.5	0.0	0.4		0.4	98.7	0.5	10	2.37
19	do Springfield,	3.2	0.0	1.6		0.6	94.6	1.7	34	2.60
20	Tertiary—Barnstable,	0.0	0.0	0.1		0.3	99.6	0.8	16	2.72
21	do Gloucester,						100.	0.7	14	2.71
22	Sandstone, (Red,)—Deerfield,	0.3	2.6	0.8		0.7	95.6	3.4	68	2.53

23	Sandstone, (Red,)—Longmeadow,	3.2	0.5	3.2		0.6	92.5	3.2	64	2.43
24	do do Wilbraham,	6.1	2.0	1.0		0.8	90.1	2.5	50	2.60
25	do do W. Springfield,	4.1	3.8	4.3		0.7	88.1	2.7	54	2.46
26	do (Gray,)-Granby,	2.7	1.8	0.6		0.8	94.1	3.0	60	2.51
27	Graywacke Soil—Dorchester,	7.6	2.1	1.8		1.0	87.5	4.5	90	2.37
28	do Roxbury,	4.4	3.8	2.3		1.4	88.1	3.9	78	2.43
29	do Brookline,	6.0	5.3	3.1		1.4	84.2	5.8	116	2.34
30	do Walpole,	2.6	5.5	1.9		0.8	89.2	3.1	62	2.31
31	do Dighton,	2.1	3.4	1.9		0.5	92.1	1.5	30	2.34
32	do Middleborough,	1.2	3.7	2.1		0.9	92.1	1.6	32	2.48
33	do Quincy,	2.1	5.0	2.4		1.5	90.0	3.5	70	2.44
34	do W. Bridgewater,	3.4	2.3	1.2		0.6	92.5	2.5	50	2.40
35	do Watertown,	5.6	5.5	1.9		1.1	85.9	4.6	92	2.27
36	do Halifax,	3.3	2.7	0.3		0.8	92.9	1.0	20	2.45
37	do Cambridge,	2.8	3.5	1.8		0.2	91.7	2.6	52	2.45
38	do Taunton,	4.7	2.4	1.8		0.8	90.3	1.8	36	2.44
39	do Attleborough, east part,	2.0	4.1	0.5		0.6	92.8	2.8	56	2.48
40	do do west part,	2.5	6.6	1.9		2.0	87.0	3.7	74	2.21
41	Argillaceous Slate—Lancaster,	5.0	4.5	4.6		0.9	85.0	5.6	112	2.25
42	do Sterling,	6.1	4.6	1.8		0.5	87.0	2.6	52	2.32
43	do Townsend,	6.2	5.0	1.0		1.0	86.8	3.5	70	2.31
44	Limestone, (Magnesian,)—Marlborough,	4.4	2.0	1.4		0.5	91.7	3.0	60	2.43
45	do Lanesborough,	3.0	4.2	1.1		0.8	90.9	3.6	72	2.39
46	do Great Barrington,	3.6	5.0	1.7		0.5	89.2	3.5	70	2.56
47	do Adams,	2.2	3.3	1.5		0.4	92.6	2.8	56	2.46
48	do Williamstown,	3.1	2.0	2.8		0.6	91.5	5.5	110	2.39
49	do Stockbridge,	2.3	5.2	3.9		0.7	87.9	6.0	120	2.45
50	do Pittsfield,	5.4	5.3	1.0		0.7	87.6	3.0	60	2.39
51	do Sheffield,	2.7	4.2	1.8	0.8	0.5	90.0	5.1	102	2.27
52	do W. Stockbridge,	4.0	5.2	1.0	3.2	1.6	85.0	4.5	90	2.39
53	Mica Slate Soil—West Boylston,	6.0	5.1	0.9		0.6	87.4	4.2	84	2.31
54	do do Webster,	5.5	3.1	1.3		1.0	89.1	5.5	110	2.31
55	do do Lunenburg,	5.0	3.4	0.8		1.1	89.7	4.3	86	2.29

Number.	Name and Locality of the Soil.	Soluble Geine.	Insoluble Geine.	Salts of Lime. Sulphate.	Salts of Lime. Carbonate.	Salts of Lime. Phosphate.	Granitic Sand.	100 grains heated to 300° F. absorbed in 24 hours.	Absorbing Power in Proportional Numbers.	Specific Gravity.
56	Mica Slate Soil—Stockbridge, Mt.	3.0	5.5	0.2		1.5	89.8	5.3	106	2.40
57	do do Chester Village,	6.0	3.5	1.5		1.5	87.5	4.7	64	2.41
58	do do Bradford,	6.5	6.8	2.0		1.2	83.5	6.5	130	2.26
59	do do West Newbury,	3.0	5.5	3.5		1.0	87.0	4.8	96	2.37
60	do do Methuen,	2.9	2.2	1.5		0.6	92.8	0.9	18	2.53
61	do do Pepperell,	3.8	7.0	1.6		0.7	86.9	6.2	124	2.27
62	do do Norwich,	4.1	4.3	1.2		0.6	89.8	5.3	106	2.36
63	do do Conway,	2.0	4.5	1.7		1.1	90.7	3.2	64	2.53
64	Talcose Slate Soil—Chester, west part,	1.5	2.1	3.1		1.0	92.3	3.1	62	2.54
65	do do Charlemont,	3.8	2.2	1.4		0.6	92.0	3.5	70	2.45
66	Talco-micaceous Slate—Florida,	3.2	8.4	2.4		2.0	84 0	5.8	116	2.35
67	do do Hancock,	6.2	5.8	1·5		1.0	85.5	2.3	46	2.31
68	Gneiss Soil—Tewksbury,	4.3	3.9	1.2		0.8	89.8	3.5	70	2.41
69	do Stow,	4.0	3 0	2.0		1.0	90.0	3.8	76	2.41
70	do Bolton,	4.6	3.4	2.1		0.9	89 0	3.8	76	2.40
71	do Uxbridge,	2.6	3.0	2.9		0.9	90.6	3.5	62	2.36
72	do Mendon,	2.6	2.5	2.4		0.7	91.8	3.4	68	2.51
73	do Tyngsborough,	4.5	1.8	0.6		0.6	92.5	2.6	52	2.45
74	do Holden,	3.9	4.7	1.4		1.4	88.6	5.0	100	2.37
75	do Dudley,	4.0	4.6	1.9		0.7	88.8	5.3	106	2.35
76	do Templeton,	5.2	4.1	2.7		0.5	87.5	5.1	102	2.26
77	do Rutland,	7.1	5.3	1.9		1.2	84.5	6.5	130	2.27

78	do	Westminster,	5.3	3.8	2.2	3.0	0.7	85.0	4.6	92	2.26
79	do	Royalston,	6.0	3.6	1.9		0.6	87.9	5.4	108	2.27
80	do	Fitchburg,	5.4	3.3	1.0	2.1	0.7	87.5	3.4	68	2.44
81	do	Petersham,	5.7	4.8	2.4		0.4	86.7	4.5	90	2.36
82	do	New Braintree,	6.0	6.3	1.7		0.8	85.2	6.7	134	2.34
83	do	Palmer,	5.7	2.7	2.1		0.6	88.9	2.6	52	2.49
84	do	Enfield,	7.2	4.9	2.5		1.0	84.4	6.4	124	2.29
85	do	New Salem,	3.2	2.7	1.5		0.7	91.9	3.7	74	2.44
86	do	Leverett,	3.3	3.7	2.8		0.7	89.5	4.4	88	2.49
87	do	Hardwick,	6.3	3.3	2.1		0.6	87.7	4.9	98	2.36
88	do	Ware,	5.3	0.7	1.9		0.6	91.5	2.3	46	2.58
89	do	Grafton,	4.5	3.5	2.1		0.6	89.3	5.4	108	2.39
90	do	Brimfield,	5.3	2.1	1.0		0.4	91.2	3.7	74	2.46
91	do	Leicester,	3.9	2.9	2.8		1.3	89.1	5.2	104	2.48
92	do	Otis,	4.7	5.4	1.8		1.1	87.0	6.0	120	2.34
93	do	Becket,	8.3	2.4	2.9		1.1	85.3	6.0	120	2.27
94	do	Buckland,	5.4	2.0	2.1		0.7	89.8	2.8	56	2.51
95	do	Wareham,	2.0	0.6	1.2		0.4	95.8	0.9	18	2.68
96	do	Sturbridge,	5.1	3.7	2.3		0.4	88.5	2.7	54	2.50
97	do	Brimfield, not cultivated,	0.6	3.8	1.1		0.5	94.0	3.7	74	2.60
98	do	West Brookfield, not cultivated,	1.5	5.1	1.6		0.5	91.3	4.7	94	2.68
99	do	Oakham,	4.8	2.2	1.4		0.3	91.3	3.0	60	2.45
100	do	Athol, decomposing Gneiss,	0.3	5.3	2.0		0.3	92.1	3.0	60	2.60
101	Granite Soil—	W. Hampton,	1.2	4.0	1.6		0.8	92.4	2.2	44	2.60
102	do	Concord,	7.1	2.0	1.6		0.5	88.8	2.5	50	2.50
103	do	Duxbury,	4.0	2.0	0.8		0.7	92.5	2.4	48	2.43
104	do	Andover,	5.1	7.5	1.6		0.6	85.2	4.4	88	2.29
105	Sienite Soil—	Lynnfield,	5.1	5.2	1.4		0.6	87.7	4.4	88	2.29
106	do	Marblehead,	5.1	5.0	2.7		0.6	86.6	5.8	116	2.35
107	do	Manchester,	6.5	3.4	0.8		0.6	88.7	4.0	80	2.40
108	do	Gloucester,	2.4	2.2	1.5		0.3	93.6	2.8	56	2.25
109	do	Lexington,	5.4	3.9	2.6		0.6	87.5	6.5	130	2.24
110	do	Danvers,	3.8	6.9	2.7		0.7	85.9	5.0	100	2.34

Number.	NAME AND LOCALITY OF THE SOIL.	Soluble Geine.	Insoluble Geine.	Salts of Lime.			Granitic Sand.	100 grains heated to 300° F. absorbed in 24 hours.	Absorbing Power in Proportional Numbers.	Specific Gravity.
				Sulphate.	Carbonate.	Phosphate.				
111	Sienite Soil—Newbury, ...	5.0	5.5	1.0		0.5	88.0	5.3	106	2.36
112	do Dedham, ...	7.0	4.7	1.0		1.3	86.0	6.2	124	2.24
113	do Wrentham, ...	5.6	5.6	0.8	0.4	1.5	86.1	3.6	72	2.43
114	do N. Bridgewater, ...	2.2	5.9	2.5		0.7	88.7	3.7	74	2.36
115	do Weymouth, ...	2.6	5.1	2.2		0.6	89.5	4.0	80	2.35
116	do Sharon, ...	6.9	3.2	1.7		0.5	87.7	3.2	64	2.32
117	do Marshfield, ...	1.6	2.9	1.1		0.8	93.6	3.7	74	2.45
118	do Abington, ...	2.7	3.7	1.5		0.8	91.3	2.7	54	2.46
119	Porphyry Soil—Kent's Island, Newbury, . .	5.7	4.6	3.3		0.4	86.0	6.3	126	2.26
120	do Medford, ...	8.7	4.2	2.6		0.8	83.7	6.6	132	2.17
121	do Malden, ...	5.2	4.1	3.5		1.6	85.6	6.8	136	2.26
122	do Lynn, ...	4.3	3.5	1.8		0.6	89.8	5.9	118	2.29
123	Greenstone Soil—Ipswich, ...	2.8	9.4	0.7		0.2	86.9	3.6	72	2.22
124	do Woburn, ...	7.7	4.6	1.3		1.2	85.2	6.0	120	2.27
125	do Deerfield, .	3.2	4.3	0.1	2.0	0.3	90.1	2.7	54	2.51

Explanation of the preceding Table of Results with Remarks and Inferences.

The first and second columns need no explanation: and the character of the third and fourth will be fully understood, after reading the remarks of Dr. Dana that precede the Table. They show us the amount of nutriment in the soils of Massachusetts; also how much of it is in a fit state to be absorbed by plants, and how much of it will need further preparation. As this is probably the first attempt that has been made to obtain the amount of geine in any considerable number of soils, we cannot compare the results with those obtained in other places. They will be convenient, however, for comparison with future analysis; and we learn from them, that geine, in both its forms, abounds in the soils of the state, and that it most abounds where most attention has been paid to cultivation. It ought to be recollected, that I took care not to select the richest or the poorest portions of our soils; so that the geine in this table is probably about the average quantity. It is hardly probable that the number of specimens analysed from the different varieties of our soils is sufficiently large to enable us to form a very decided opinion as to their comparative fertility, especially when we recollect how much more thorough is the cultivation in some parts of the state than in others. It may be well, however, to state the average quantity of geine in the different geological varieties of our soils, which is as follows:

		Soluble Geine.	Insoluble Geine.
Alluvium,		2.25	2.15
Tertiary argillaceous soils,		3.94	5.22
Sandstone	do.	3.28	2.14
Graywacke	do.	3.60	4.00
Argillaceous slate	do.	5.77	4.53
Limestone,	do.	3.40	4.04
Mica slate	do.	4.34	4.60
Talcose slate	do.	3.67	4.60
Gneiss	do.	4.30	3.40
Granite	do.	4.05	3.87
Sienite	do.	4.40	4.50
Porphyry	do.	5.97	4.10
Greenstone	do.	4.56	6.10

One fact observable in the above results may throw doubts over the fundamental principles that have been advanced respecting geine; viz., that it constitutes the food of plants, and that they cannot flourish without it. It appears that our best alluvial soils contain less geine, in both its forms, than any other variety, except those very sandy ones that are not noticed in the above results, because their number is so small. Ought we hence to infer that alluvium is a poor soil? I apprehend that we can infer nothing from this fact against alluvial soils, except that they are sooner exhausted than others, without constant supplies of geine. For if a soil contain enough of this substance abundantly to supply a crop that is growing upon it, that crop may be large although there is not enough geine to produce another. Now analysis shows that our alluvial soils contain enough of geine for any one crop: and I apprehend that their chief excellence consists in being of such a degree of fineness that they allow air, moisture, and lime, rapidly to convert vegetable matter into soluble geine, and yield it up readily to the roots of plants: but I presume that without fresh supplies of manure, they would not continue to produce as long as most of the other soils in the state. A considerable part of our alluvia are yearly recruited by a fresh deposite of mud, which almost always contains a quantity of geine and of the salts of lime, in a fine condition for being absorbed by the rootlets of plants. And on other parts of alluvial tracts, our farmers, I believe, are in the habit of expecting but a poor crop unless they manure it yearly. Yet so finely constituted are these soils, that even if exhausted, they are more easily restored than most others; so that taking all things into the account, they are among the most valuable of our soils; and yet I doubt whether they produce as much at one crop as many other soils; though the others perhaps require more labor in cultivation.

The amount of soluble and insoluble geine obtained by Dr. Dana's method of analysis, ought to correspond pretty nearly with the amount of organic matter obtained by the old method; and by comparing the two tables of results that have been given, it will be seen that such is the fact. Several circumstances, however, besides errors of analysis, will prevent a perfect agreement. In the first place, by the old method of analysis, 100 grains of the soil are weighed before expelling the water of absorption; but by the new method, not until after

its expulsion. Again, by the old method only the very coarse parts of the soil are separated by the sieve : but a fine sieve is used by the new mode, and this removes nearly all the vegetable fibre, which by the other method is reckoned a part of the organic matter. Other causes of difference might be named : and hence we ought not to expect a perfect agreement in the results of the two methods.

The three next columns in the Table contain the salts of lime in our soils. I have already described the infrequency of the carbonate; but very different is the case with the sulphate and the phosphate which were found in greater or less quantity, in every soil analysed. In respect to the sulphate of lime, or gypsum, it may not be unexpected that we should find it in all soils, since we know it to occur in all natural waters throughout the state; and we cannot conceive of any other source from which the water could have derived it, except the soil. But the phosphate of lime has generally been supposed to be much more limited, nay to be scarcely found in soils, except where animal substances have been used for manure. It is possible that in all the soils which I have analysed, such might have been its origin, though not very probable. Yet there is strong reason to believe, that this salt is a constituent of all soils in their natural state. The arguments on this subject are stated so ably by Dr. Dana that I need only quote from his letter.

"When we consider that the bones of all graminivorous animals contain nearly 50 per cent of phosphate of lime, we might be at liberty to infer the existence of this principle, in the food, and, consequently, in the soil, on which these animals graze. If we look at the actual result of the analysis of beets, carrots, beans, peas, potatoes, asparagus, and cabbage, we find phosphate of lime, magnesia, and potash, varying from 0.04 to 1.00 per cent of the vegetable. Indian corn too, by the analysis of the late Professor Gorham, of Harvard College, contains 1.5 per cent phosphate and sulphate of lime. It may be said that this is all derived from the manure. We shall see by and by. Let us look at the extensive crops often raised, where man has never manured. Rice, wheat, barley, rye, and oats, all contain notable portions of phosphate of lime, not only in the grain but in the straw, and often in the state of superphosphats. The *diseases* too, *ergot* and *smut*, show *free phosphoric acid*. Can it be

that, owing to certain electrical influences of the air, in particular seasons, lime is not secreted by the plant to neutralise the free acid? May not this be a cause of smut and ergot? Does it not point out a remedy? Take too the cotton crop of our country. What vast quantities of phosphats do we thus annually draw from the soil? Cotton gives one per cent ashes, of which 17 per cent is composed of phosphat of lime and magnesia. The like is true of tobacco. It contains 0.16 per cent of phosphat of lime. If we turn to the analysis of forest trees, we find that the *pollen* of the *pinus abies*, wafted about in clouds, is composed of 3 per cent phosphat of lime and potash. May not this too be one of nature's beautiful modes of supplying phosphoric acid to plants and to soils? If, as the late experiments of Peschier have proved, sulphat of lime, in powder, is decomposed by growing leaves, the lime liberated, and the sulphuric acid combining with the potash in the plant, why may not phosphat of lime, applied by *pollen*, act in the same way? At any rate, the existence of phosphat of lime in our forest soils is proved not only by its existence in the pollen, but by its actual detection in the ashes of pines and other trees.—100 parts of the ashes of *wood* of *pinus abies* give 3 per cent phos. iron; 100 parts of the ashes of the *coal* of *pinus sylvestris* give 1.72 phos. lime, 0.25 phos. iron; 100 parts of ashes of oak coal give 7.1 phos. lime, 3.7 phos. iron;

100 ashes of		Bass wood	5.4	"	3.2	"
"	"	Birch	7.3	"	1.25	"
"	"	Oak wood	1.8	"		
"	"	Alder coal	3.45	"	9.	"

"These are the calculated results from Berthier's very accurate analyses, and those very curious crystals—detected in some plants—the "*raphides*" of De Candolle, are some of them bibasic phosphats of lime and magnesia. Phosphat of iron, we know, is common in turf; bog ore, and some barren and acid soils owe their acidity to *free* phosphoric acid. If we allow that our untouched forest soil contains phosphat of lime, it may be said, that this, being in small quantity, will be soon exhausted by cultivation, and that the phosphats, which we now find in cultivated fields, rescued from the forest, is due to our manure;—I give you the general result of my analysis of *cow dung*, as the best argument in reply. My situation and duties

have led me to this analysis. I give you it, in such terms as the farmer may comprehend: water, 83.60; hay, 14.; biliary matter, (bile resin, bile fat and green resin of hay,) 1.275; geine combined with potash, (vegetable extract,) 0.95; albumen, 0.175."

"The hay is little more altered than by chewing. The albumen has disappeared, but its green resin, wax, sulphat and phosphat lime remain, and when we take 100 parts of dung, among its earthy salts we get about 0.23 parts phosphat, 0.12 carbonat, and 0.12 sulphat of lime. Now, a bushel of green dung as evacuated weighs about 87.5 lbs. Of this only 2.40 per cent are soluble. Of this portion only 0.95 can be considered as soluble geine."

Western Soils.

In addition to the preceding arguments respecting the existence of phosphate of lime in the soils, I would state that I found it in every analysis which I have made of the Berkshire marls, the results of which I shall soon present. I have also recently analysed five specimens of soils from Ohio and Illinois, presented to me by H. G. Bowers, Esq., formerly of Northampton, in this state, and now resident in Illinois. They were taken from some of the most productive spots in those states, and, in regard to some of them, it is certain, that no animal or any other manure has ever been applied by man, and at least one of them seems not to have been cultivated, so far as I can judge from its appearance. Yet all these soils contain phosphate of lime. The following are the results of their analysis; which I give, partly because of the subject under consideration, and partly because I thought it might be gratifying to compare the composition of some of the best soils at the west with those in Massachusetts.

	Soluble Geine.	Insoluble Geine.	Sulphate of Lime.	Phosphate of Lime.	Carbonate of Lime.	Granitic Sand.	Water of Absorption.	Remarks.
Rushville, Illinois,	7.4	2.5	3.4	0.6	1.5	84.6	6.3	
Sangamon co., do.	4.9	5.6	1.2	0.4	1 3	86.6	6.3	
Lazelle county, do.	7.6	13.8	1.4	0.4	3.3	73.5	9.5	Apparently never cultivated.
Peoria county, do.	3.1	4.8	3.5	1.0		87.6	5.7	
Sciota Valley, Ohio,	4.5	6.7	2.1	0.9	2.8	83.0	5.3	Cultivated 14 years without manure

The above soils are evidently of the very first quality : the geine being in large proportion, and the salts quite abundant enough, while there is still a small supply of carbonate of lime to convert more insoluble into soluble geine, whenever occasion demands. Still, if we compare the preceding analyses with some of those that have been given of the Massachusetts soils, the superiority of the western soils will not appear as great as is generally supposed. And there is one consideration resulting from the facts that have been stated respecting geine, that ought to be well considered by those who are anxious to leave the soil of New England that they may find a more fertile spot in the West. Such soils they can undoubtedly find ; for geine has been for ages accumulating from the decomposition of vegetation in regions which have not been cultivated : and for many years, perhaps, those regions will produce spontaneously. But almost as certain as any future event can be, continued cultivation will exhaust the geine and the salts, and other generations must resort to the same means for keeping their lands in a fertile condition as are now employed in Massachusetts, viz., to provide for the yearly supply of more geine and more salts.

Importance of the Salts of Lime.

To return from this digression, I apprehend that the importance of the salts of lime in a soil is but little appreciated by farmers in general. Their crops may fail, although they have manured and tended them well ; but it is almost always easy to find a cause that satisfies, in the character of the season ; but hard to convince them that the failure may have been owing to the deficiency of a single grain in a hundred, of some substance, that can be discovered when present, only by chemical examination. And yet, I doubt not many a crop has failed from the want of that one per cent of sulphate or phosphate of lime. Facts, indeed, seem to me to warrant the conclusion, that, without lime in some form, land will not produce any valuable vegetation.

Granitic Sand.

The eighth column contains the granitic sand in our soils, according to Dr. Dana's definition. Its amount is obtained by subtracting the amount of the geine and salts of lime from 100. No notice is taken in this case of the water of absorption, because the 100 grains operated upon were not weighed out till that water had been driven off.

This granitic sand consists of all the earthy and metallic ingredients of the soil except lime, which has been separated by the process. But concerning the nature and uses of the earthy part of a soil, enough has already been said.

Power of the Soils to absorb Water.

It is generally known, that soils possess the power of absorbing moisture in different degrees. This power depends more upon the geine of soils, than any other principle. Alumina stands next on the list in its degree of absorbing power; next, carbonate of lime; and least of all, silica. Hence there ought to be a general correspondence between the absorbing power of a soil and its fertility; and, therefore, this property affords some assistance in estimating the value of a soil. On this account I was desirous to get the power of absorption possessed by the soils of Massachusetts. 100 grains were heated to 300° F. and then exposed on a small earthen plate for 24 hours, in a cellar, whose temperature remained nearly the same from day to day. The thermometer stood in it at 37° F.; and the *dew point*, by Daniell's Hygrometer, was 33° F. At the end of 24 hours, the soils in the plates were again weighed, and the number of grains which they had gained was put into the ninth column. For the sake of showing at a glance the absorbing power, it is expressed in the tenth column by proportional numbers; 5 grains absorbed, being equal to 100.

I find the winter to be a most unfavorable time for experiments of this sort; and I place but little reliance upon the results which I have obtained. As the experiments were performed, however, with a good deal of care, I thought it best to give them, after stating all the circumstances under which they were made.

Power of Soils to retain Water.

Still more unfavorable is the season of winter for experiments upon the power of soils to retain water ; a power which is by no means always proportional to their absorbing power. I did, however, attempt to perform experiments of this sort, by adding 100 grains of water to 200 grains of soil upon broad earthen plates, and exposing them to the sun in a clear day, for three hours. As it was impossible, however, to go through with all the soils in one day in this manner, the results on different days cannot be compared ; because evaporation is very different upon different days, even though the air be clear, and the wind westerly, and the temperature nearly the same ; which were the circumstances under which the experiments were performed. I will give here, however, some of the results obtained by this process ; although I cannot see that they are of much importance. 200 grains of soil, with 100 grains of water, lost, in three hours, as follows :

January 15th.			*January 16th.*		
No. of Soil.			No. of Soil.		
2	lost	74.5 gr.	43	lost	85.8 gr.
45	"	90.6	44	"	82.5
47	"	88.0	50	"	92.9
51	"	83.5	58	"	83.5
54	"	83.4	60	"	92.7
56	"	90.1	63	"	89.6
59	"	91.0	65	"	85.3
87	"	86.6	67	"	85.8
94	"	94.0	70	"	88.1
96	"	83.0	71	"	83.5
122	"	81.5	77	"	75.7
			79	"	80.2
January 16th.			89	"	79.1
8	"	81.7	90	"	87.4
40	"	75.4	93	"	77.5
41	"	78.4	98	"	82.7

January 16th.

No. of Soil.		
101	lost	76.7 gr.
104	"	80.3
106	"	83.6
108	"	85.4

January 23d.

11	"	59.7
12	"	58.2
14	"	64.7
22	"	53.8
28	"	53.9
33	"	52.0
34	"	59.4
39	"	57·8
42	"	55.2
46	"	52.5
48	"	54.5

February 10th.

9	"	55.0
10	"	51.5
13	"	57.0
17	"	69.3
19	"	57.0
29	"	60.0
32	"	55.5
35	"	57.5
37	"	63.0
38	"	55.0
52	"	61.5

February 23d.

No. of Soil.		
55	lost	57.5 gr.
58	"	58.0
61	"	66.5
62	"	63.0
64	"	66.0
66	"	68.0
68	"	65.0
69	"	62.0
73	"	63.5
74	"	65.0
75	"	55.9
76	"	64.9
78	"	57.3
80	"	64.7
81	"	55.0
82	"	64.7
83	"	57.0
84	"	58.9
85	"	54.3
86	"	55.3
88	"	70.1
91	"	74.3
92	"	65.6
95	"	77.3
97	"	64.0
99	"	62.0
100	"	53.0
102	"	66.0
103	"	60.0
105	"	60.0

Specific Gravities.

The weight of the different soils, compared with one another and with water, is given in the last column of the table. As a general

fact, it will be seen that the most sandy soils are the heaviest, and those containing the most geine, the lightest. This character, however, is not of very great importance. Pure water is here considered as the standard, or as unity ; and the numbers in the table show how much heavier the soils are than water.

General Conclusions.

Without stopping to notice some things of minor importance, I will state at once the most important conclusions that have forced themselves upon my mind, from all my examinations and analyses of our soils, respecting their deficiencies and the means of remedying them.

First, the grand desideratum in our soils is calcareous matter ; that is, carbonate of lime.

The second desideratum is an additional quantity of geine ; that is, a larger supply of the food of plants.

Hence, thirdly, the great object of the agricultural chemist should be, to discover and bring to light new supplies of both these substances.

The discovery of either of them would, indeed, be of no small value ; but it is a principle that ought never to be lost sight of, that an additional quantity of lime in the soil, will commonly require an additional quantity of organic matter, and an increase of the latter, will be far more serviceable, if attended by an increase of the former.

These fundamental principles and conclusions I have kept in view continually ; and will now proceed to show with what success I have searched for new sources of lime and of geine. I shall begin with the former as the most important, because the farmer already possesses the means of increasing the quantity of his manure, but not of obtaining calcareous matter ; for, with the exception of Berkshire county, Massachusetts is very deficient in limestone.

2. Marls.

No form of calcareous matter is so valuable in agriculture as rich marl. This term, however, has been till recently very loosely

applied ; often meaning nothing more than loose clay, entirely destitute of lime. But all accurate writers now understand it to mean a friable mixture of lime and clay ; although the term is extended to beds of calcareous shells that are somewhat hard. Till within a few years, this substance has been neglected in our country ; but its remarkable effects in some of our middle and southern states, have awakened the public attention ; and it is now sought after with no small avidity. From the nature of our rocks, I had no hope of finding rich marls in any other part of the state except the County of Berkshire. From that part of the state, many years ago, I had seen a specimen that appeared very rich. I prepared therefore to go in search of the bed from which it was taken ; and by the directions of Professor Dewey, I found it in Pittsfield, near the east part of the village, on the borders and in the bottom of a pond covering several acres. It seemed to me very probable that similar beds must occur in other parts of that county where limestone prevails. My search was soon rewarded by the discovery of an extensive bed in the northwest part of Stockbridge on land of Mr. Buck ; whose thickness was about two and a half feet, and probable extent, very great. Also a second bed in the same town, only four miles from the courthouse in Lenox. Also a third bed in the north-east part of Lee, at the Mills of Sedgwick and Co., the thickness of which, in some places, is about ten feet; though its extent is but a few acres. Also, several beds in West Stockbridge in various parts of the town. The limited time which I gave to these researches did not allow me to make but slight examinations in other towns. But I have little doubt that similar beds of marl will be found in various other places in the county ; especially in Sheffield, Great Barrington, Egremont, Alford, Richmond, Lanesborough, New Ashford, and perhaps in Williamstown, Adams, Cheshire, Dalton, and New Marlborough. I am confirmed in this opinion from the fact that since I visited the county several other beds have been discovered.

A second bed has been found in Pittsfield, about a mile south-east of the village. Also a bed in Stockbridge, a little east of the village. For specimens from both which places, I am indebted to Professor Dewey. A third bed has been found covering several acres in the north-west part of Lee, near a pond, on land of Messrs. Lemuel

and Cornelius Bassett. The thickness of the marl, which commences about a foot below the surface, is in some places from four to seven feet, and in others, from ten to twelve feet; and from 200 to 300 loads have been taken from it the present winter by the Messrs. Bassett. Specimens from all the beds that have been described will be found in the collection accompanying this Report. (See Nos. 148, 149, 150, 151, 152, 153, 172, 173, 174, 175.) I am informed also, that a small bed exists in Tyringham, and another in Stockbridge, on the road leading to Lenox.

The purest of these marls when dry, are almost as white as chalk, and much lighter than common soil, as may be seen from the specific gravities of a part of them in the table of their analysis below. When wet they are of a light gray color, especially if they contain much organic and earthy matter: indeed the degree of their whiteness is no bad index of the quantity of lime that they contain. When wet they are quite plastic and adhesive: when dry, they fall into a fine powder. Hence they are in a most favorable state for being spread upon land. They are found almost exclusively in swampy ground, generally in quite wet swamps, and are always covered by a stratum, often several feet thick, of black vegetable matter approaching to peat. Hence, as these swamps are rarely excavated, the marl is not apt to be discovered; or if found, it is supposed to be nothing more than white clay and sand, which, indeed, it does very much resemble. In order to ascertain the presence of marl in a swamp, I prepared an iron rod, several feet long, near the end of which was a groove, in fact it formed a sort of auger. When pressed into the ground and withdrawn, it would always retain in the groove some of the matter from the bottom of the hole, and in this way, in a few minutes, not only the existence of marl might be ascertained, but the thickness of the bed. Yet after all, since the swamps where it occurs are usually very wet, and easily penetrated, a rough pole is better for discovering marl and its thickness, than the iron borer which I have described. For some of it will adhere to a pole plunged into it, even though that pole must be drawn through several feet of vegetable mud above it. And if the pole be plunged to the bottom of the bed, the distance along the pole covered with marl, will show the thickness of the bed; except that the lower extremity of the pole will

show beneath the layer of marl the clay or sand as far as they were penetrated; and this extent must be subtracted from the whole length covered with marl. I have been thus particular in describing the method of searching for marls, in the confidence that if gentlemen residing in the towns above mentioned will adopt it, many new beds will be brought to light.

There is a substance in the central and eastern parts of the State, in exactly the same situation as the marl of Berkshire, which resembles it also very precisely in external characters, and is also like marl very light; and yet it is not marl. It does not contain carbonate of lime, but is composed chiefly of silica. Specimens of it will be found in the collection from several places. (See No. 157, which is from Spencer; No. 169, from Barre, and No. 170, from Andover.) It is easy, notwithstanding its general resemblance, to distinguish it from marl by a few drops of vinegar, oil of vitriol, aqua fortis, or any other acid. If it be marl, the acid will produce in it small bubbles occasioned by the escape of gas—if not marl, no effervescence will be produced. And this is a universal test, which is almost infallible, for distinguishing marl in all circumstances.

One other circumstance respecting the Berkshire marl, which will aid in distinguishing it. It abounds every where with small fresh water shells, such as now occur in the ponds of that region, and therefore it is unquestionably true fresh water marl, and not shell marl. The epidermis of the shell is usually gone. Such shells are rarely found in much quantity where lime does not exist, although I have seen them in mud that did not effervesce. But their presence should lead us to search carefully for calcareous matter: for how can these animals form their shells without lime?

The manner in which these Berkshire marls were formed, is very obvious. They result from the carbonate of lime brought into ponds by water, and there at length deposited. After the pond is filled nearly up, vegetables begin to grow over the marl, and thus at length a deposite of peaty matter covers the marl. The process, I doubt not, is now going on in most limestone countries, and thus a vast amount of valuable matter for agriculture is accumulating in spots usually regarded as waste places.

The Berkshire marls, above described, appear to me to be some

of the richest and best that ever occur. Marls are usually valued only for the calcareous matter which they contain. But by adopting Dr. Dana's method of analysis, we find that they also contain no small quantity of soluble and insoluble geine, derived from the vegetable matter that covers them. This must make them still more valuable when applied to the soil. They contain likewise a small portion of phosphate of lime, increasing their value still more: while the granitic sand in them, the only part that is of no value, is in most cases extremely small. The following are the results of the analysis of the ten specimens in the Government collection.

No.	LOCALITY.	Soluble Geine.	Insoluble Geine.	Phosphate of Lime.	Carbonate of Lime.	Carbonate of Magnesia.	Granitic Sand.	Water of Absorption.	Specific Gravity.	REMARKS.
148	Stockbridge, (Mr. Buck's farm,) . .	4.3	4.6	0.7	73.4	0.15	13.5	3.3	1.82	2½ feet thick.
151	do south-east of the village, .	5.0	8.9	0.6	46.0	trace.	36.6	2.9		
149	Pittsfield, east of the village, . . .	3.1	3.5	0.7	86.4	0.46	3.1	3.0	1.82	4 feet thick at least.
152	do S. W. of village (Mr. Strong's lot)	3.1	3.2	0.4	64.8	trace.	25.2	1.9		
150	West Stockbridge, (Mr. Reed's land,) .	1.7	5.0	0.5	74.8	0.53	14.7	2.8	1.61	
153	Lee, (Sedgwick & Co's mills,) . .	1.2	2.1	1.0	93.2	no trial	0.9	1.6	1.89	Exposed to the action of running water.
172	do (L. Bassett's bed, near the surface,)	1.8	2.2	1.4	93.0	do	2.2	0.4		9 to 12 feet thick.
173	do do 10 ft. below the surface,	1.6	2.8	1.0	88.8	do	4.4	1.4	1.75	
174	do (C. Bassett's bed,)	2.6	3.4	1.2	86.2	do	5.0	1.6		Nos. 172, 173 and 174 are from the same bed.
175	do (Sedgwick's mills,)	0.8	4.4	1.0	83.6	do	9.2	1.0		Not exposed to the action of running water.

The amount of calcareous matter in these marls is unusually large, with the exception of one of the specimens from Pittsfield, and another from the east part of Stockbridge. And since only a small quantity of these was sent to me, which probably might have been taken from the margin of the beds, it is not certain, that my analysis exhibits the average proportion of calcareous matter even in those beds. Again, most marls are only in part pulverulent, or easily crumbled down, and they require a long time after being mixed with the soil, before they will exert a favorable action upon it. But these are all in a state best adapted for immediate use; and when we add to these considerations those already made concerning the other ingredients of these marls, I cannot but feel that Berkshire possesses in them a very great treasure. I doubt not but an inexhaustible supply may be found there, not only for the county but for exportation. And since the most numerous beds yet discovered occur very near the point (West Stockbridge) where two great rail roads are soon to intersect, I cannot doubt that this marl will be among the articles of export, at least a considerable distance. The marls of New Jersey and Virginia, it is well known, are already beginning to be transported a great distance. And if any marls are rich enough to be thus conveyed by land or water, surely those of Berkshire must be of the number. It will doubtless require a long time to satisfy many of our farmers of the value of marl: and especially as we may expect many failures from applying this marl in improper quantity, or in the neglect of collateral circumstances essential to success. But unless a vast amount of experience in the use of marl in Europe and in this country is to be set aside as a ground of judgment, these marls must sooner or later work an important improvement in a portion of the agriculture of this State.

There is an important fact derived from the analysis of soils that have been given, relative to the character of those in Berkshire county. It had formerly been supposed, that the soils of that county contain so much lime, that marls would be of no service there. But it appears that they contain scarcely any more of this substance, either in the form of carbonate, sulphate, or phosphate, than the other soils of the state. At least, the specimens analysed do not; and these were taken at random from fields underlaid by limestone; so that

probably they show about the average quantity of lime in the soils of the county; though I doubt not that soils may be found there containing more of this substance. I think this may be a safe rule to follow by the farmers of that county. If a soil effervesces with vinegar, or other acids, they may infer that marl will be of little service. If it do not effervesce, they may safely apply marl. And judged of by this rule, I doubt not that four out of five of the Berkshire soils will be found to need it.

In what Quantity and Mode shall Marl be applied?

I do not conceive that it falls within the sphere of duties assigned me by the government, to go into details respecting the mode and the quantity in which marl shall be applied, except so far as these questions can be answered by agricultural chemistry. It is well known that, in many instances, lands have been injured by over marling; and hence one is met everywhere with the questions above suggested. And certain it is, that no general rules have thus far been followed or proposed. Nor can we get any general rules on the subject until the manner in which lime acts upon soils and vegetation is understood. Here, it must be confessed, great confusion and a variety of opinions have prevailed. The action of lime is undoubtedly quite complex, and considerably different on different soils; which renders any general theory more difficult. The doctrines respecting geine, which have been explained, appear to me to throw more light on this subject than has ever before shone upon it; though some points still remain obscure; and as Dr. Dana has obligingly furnished me with his views on the subject, I shall present them without hazarding any opinion of my own; except to say, that his theory is manifestly in advance of any that has hitherto appeared.

Theory of the action of Lime on Soils, Manure, and Vegetation.

"The action of lime is threefold; each distinct. 1. It is a *Neutralizer:* 2. a *Decomposer:* 3. a *Converter.* 1. I have already alluded to some acid soils: free phosphoric acid, geic, acetic, and malic acids, also occasionally exist in a free state in soils. Here lime acts as a neutralizer. 2. Soils may contain abundant geates; parti-

cularly geate of alumina, the least of all demanded by plants. Long formed and sun-baked, they are scarcely acted on by rain or dew, and are almost useless. Here lime, by decomposing these metallic and earthy geates, forms a combination, which, in its nascent state, is readily dissolved. If the carbonate of lime acts better than the hydrate, it is because, following a well known law, double decomposition is easier than single. If any acid geine exists in the soil, or any free acids, carbonic acid is then liberated; it acts on the geate of lime, supergeates result, and these are easily soluble."

"3. The great use of lime is as a *converter*; turning solid and insoluble geine, nay, I go further, solid vegetable fibre, into soluble vegetable food. Here is the great puzzle, the point where our philosophy seems to leave us; giving us our choice, to refer this action to one of the numerous cases of mysterious '*catalytic*' change, with which we are becoming every day more and more familiar, or to explain the process by referring the whole to *saponification*. I use this word as conveying to you at once what I mean;—but I do not mean to say that the product of lime and vegetable matter is soap; but I cannot make myself more intelligible to a farmer than by saying, this lime makes compounds of vegetable matter, just as it makes soapy compounds of oil and fat. The action of lime on geine I take to be of the same nature, as its action on oils and fat. It is well established that animal and vegetable oils and fats are converted into acids by the action of alkalies, earths, oxides, and even by vegetable fibre itself. The general law is, that whenever a substance, capable of uniting with the acid of fat or oil, is placed in contact with fat or oil, it determines the production of acid. Now we have seen that alkali produces a similar change on geine; it developes acid properties. I go further, if alkali has converted vegetable oil and geine into acids, I see no reason why a similar action may not be produced by all those substances which act thus on oil. Hence *lime*, earths, and metallic oxides, convert geine into acid: as fast as this takes place, so fast it becomes soluble. Then too the long action of air on insoluble geine, rendering it soluble, is it not analogous to the action of air on oils. Both evolve in this case, vast volumes of carbonic acid, the oil becomes gelatinous and soluble in alkali; does not a similar change occur in geine? It is possible that during

the action of lime on geine, a soluble substance may be produced, bearing the same relation to this process that glycerine does to saponification. These views you will see need to be followed out experimentally. If found tenable, the most signal benefit will result. We place manures on a new foundation, on which great practical results may be erected

Practical application of the Theory of the action of Lime.

Taking the preceding principles as our guide, we may lay down a few general principles for the application of marls.

1. Enough ought to be applied to neutralise all the free acids in a soil; which may be known by its ceasing to produce acid plants, such as sorrel and pine. Generally, however, the amount required for this purpose is small.

2. It will be serviceable to add enough to convert the earthy geates of a soil into geate of lime. The richer a soil is, the greater we may conclude is the quantity of geates which it contains.

3. It will be serviceable to add enough to convert all the insoluble geine and vegetable fibre in a soil into soluble geine. Hence the richer a soil is, and the more manure is added, the more marl will it bear with benefit. Indeed, *there appears to be no danger of adding too much marl, provided a sufficient quantity of manure be also added.* Ignorance of this principle, I apprehend, is the source of most of the failures that have occured in the use of lime upon soils. Farmers have supposed that its action was like that of common manure, viz., to serve as direct nourishment to the plant; whereas it only *cooks the food*, if I may be allowed the expression, which exists in the soil, or is added along with the lime. In nearly all cases of over marling which I have read of, a fresh supply of manure has been found to be the remedy; which shows the truth of the above principle. Agriculturalists have spread marl alone, or with very little manure, upon land that has been worn out, that is, whose geine has been exhausted; and because such soils have not thereby been recruited, they have inferred that lime was injurious. Without acids, or geine, or geates, or vegetable fibre, to act upon, much excess of lime appears to operate injuriously, so as to diminish, instead of increas-

ing the crop. They have also expected a sudden and surprising increase of fertility: whereas in some cases the chief benefit seems to consist in causing the land to produce for a greater number of years, by preventing the ultimate decomposition and escape of the organic matter. In general, however, it will add also to the yearly product: but those who employ marl or lime in any form, ought to moderate their expectations, that they may not be disappointed, and to be satisfied if they can slowly and surely improve their lands as they most assuredly can do, by this substance, provided they do not expect to accomplish it by the use of lime alone.

These general rules can afford only a general guidance as to the quantity of marl proper to be used. Both marls and soils vary so much in their composition, that probably direct experiments will always be necessary to ascertain the quantity of any new variety of marl that will be most serviceable. And should any of the agriculturists of Berkshire county be disposed, as I doubt not they will be, to try the marls above described, I beg leave to recommend to them, as the best practical treatise that has been published in this country, on this subject, "An Essay on Calcareous Manures," by Edward Ruffin, Esq. of Virginia, Shellbanks, 1835. This gentleman has tried a vast number of experiments on the subject, and the perusal of his work is almost indispensable to any one who would successfully prosecute it. He says, "if the nature of the soil, its condition and treatment, and the strength of the marl were all known, it would be easy to direct the amount of a suitable dressing: but without knowing these circumstances, it would be safest to give 250 or 300 bushels to the acre of worn acid soils, and at least twice as much to newly cleared, or well manured land." (Essay pp. 54.) The marl which Mr. Ruffin used was the shell marl; a large part of which has no action on the soil for several years; nor does it contain any geine. On both these accounts probably, the Berkshire marls should be used at first in a smaller quantity; and I suspect that great care will be necessary to avoid using too much.

As to the best mode of applying marl, theory would lead us in general to prefer the method usually adopted, viz: to mix it with compost before spreading it on the soil. And I would here express a hope, that if experiments are made on the Berkshire marls, a portion

of the black vegetable matter that lies above them, may sometimes be mixed with them, to see whether it may not become converted into a geate, and thus increase the value of the marl. It would, indeed, be an important discovery, if from the same swamp both the geine and the lime could be obtained, in a state proper to sustain vegetation.

In a few instances the Berkshire marl has been tried upon cultivated land. In the North part of Stockbridge, several years ago, Mr. Hadsel Buck spread 40 loads from the bed on his farm, upon a field of grass, and he describes the effect as excellent. A mile or two east of this spot, Capt. Enos Smith, many years ago, took a quantity from another bed and spread it upon grass ground with very marked benefit. It has also been tried in Pittsfield, by Samuel A. Danforth, Esq. with encouraging success.*

I have supposed that the discovery of earthy substances containing a much less quantity of calcareous matter than the marl that has just been described, might be of great benefit to agriculture in a region so destitute of lime as Massachusetts in general. Accordingly, I have examined our clays and diluvial deposites with reference to this point and shall now give the result of my researches.

3. Marly Clay.

Most of the clays in Massachusetts contain a very small proportion of carbonate of lime, the greater part of which, however, is converted into those curious concretions called claystones, which usually contain more than 50 per cent of carbonate of lime. But it was only in the north part of Berkshire county that I found enough calcareous matter in the clay beds to be of any consequence in agriculture. In other parts of the county, I met with but few clay beds ; though I doubt not that others, besides those described below, may be found. The following analysis gives the composition of one specimen from

*I feel under great obligations to Hon. Judge Walker, and H. W. Bishop, Esq. of Lenox, for their attention and assistance in searching for beds of marl in that vicinity. Also to Charles B. Boynton, Esq. of West Stockbridge. To Sedgwick & Co., and Mr. Lemuel Bassett, I am indebted for the specimens from their marl beds in the government collection. I might name several other gentlemen in that county who have given me much assistance.

North Adams and another from Williamstown, a little southeast from the college. Both were taken from excavations for making brick.

No.	Locality.	Carbonate of Lime.	Silica and Alumina.	Prot-Oxide of Iron.	Carbonate of Magnesia.	Water of Absorption.
146	Williamstown, . .	11.7	68.0	18.0	trace.	2.3
147	North Adams, . .	28.0	43.4	26.9 (?)	0.99	0.7

Can there be a doubt, but clays so rich in calcareous matter as the above, would prove very valuable in cultivation? especially when we recollect that clay alone, destitute of calcareous matter, is of great service to some kinds of land. The bed in Williamstown, from which the specimen analysed was taken, is composed of the common plastic clay; but that in Adams, (a little east of the village,) is unusually sandy; although a part of the same bed, less calcareous, is used for making bricks. On some soils fine sand, so full of calcareous matter, must be excellent. The quantity of magnesia in it is too small to affect its value unless it be favorably. In applying it, the same principles should be our guide as in richer marls. Other beds of marly clay may be found probably, by the use of vinegar or other acids. Nos. 146 and 147 present specimens of the marly clays whose analysis has been given.

4. Calcareous Diluvium.

In the red sandstone of the valley of Connecticut river, beds of fetid limestone occasionally occur; and besides, in the towns of Springfield, West Springfield, and South Hadley, the red slaty rock contains a few per cent of carbonate of lime. In early times this rock has been extensively worn away, and the small fragments and fine sand or clay, thence resulting, have been piled up over the greater part of those towns. This accumulation of detrital matter, I call *diluvium;* and on applying acids to it, in very many places in the towns above named, I found it strongly to effervesce, especially when dug from a litle depth. The lime serves as a cement, so that in most places it is almost as hard as a rock, and requires a

good deal of labor to get it up. But exposed to wet, heat, and cold, it at length crumbles down, and becomes fit to spread upon land ; although the size of the pebbles often might injure grass fields, unless it were separated by means of a riddle. Since this diluvium was deposited, a thick layer, first of clay, and above this, of sand, has been brought over most of the region, so that the diluvium appears only in those places where the sand and clay have been worn away. But this occurs so often that it is accessible in a multitude of places. I will mention the banks of Agawam river, a little west, and also south, of the village of West Springfield ; also at the south end of the village of Springfield, in several places along the banks of the small river on which stand the lower "Water Shops." In one spot on the north bank, is an elevation belonging to the United States' Government, which ten years ago was nothing but a barren sand hill. A large quantity of this diluvium, and of the disintegrating slaty rock beneath it, was carted upon this spot, and not only has it fixed the sand, but produced a coating of clover, grass, and young locust bushes. I was there informed, that near the same spot, six or eight years ago, some of this diluvium was put upon a small sandy ploughed field, and that the good effects are still visible. In another case eight years ago, some of it was mixed with a small quantity of hog manure, and the land still produces better crops. The testimony here, and also at Chicopee Factory Village, as well as in West Springfield, was, that wherever this diluvium is spread, clover soon makes its appearance ; a result almost uniformly attending the judicious application of marl.

In the banks of Chicopee river, in numerous places from its mouth nearly to Putts Bridge, thick deposites of this diluvium appear. An enormous bed of it exists on the east bank of Connecticut river, a little south of the village at South Hadley Canal. It occurs, also, in abundance, a little south of the village of South Hadley. I have searched in vain for it in other parts of the valley of the Connecticut. No where else in Massachusetts does the red sandstone appear to contain enough of carbonate of lime to make its detritus sensibly calcareous. And although I have been told, on good authority, that in the vicinity of Hartford and Middletown, Ct., the diluvium does effervesce with acids, yet after repeated trials in

various places from Massachusetts to Middletown, I have not found any that was sensibly calcareous. At present, therefore, I must consider this variety confined to the three towns above named; though I doubt not that I might safely add Longmeadow and Wilbraham. I have analysed only three specimens; but these probably will give us about the average amount of carbonate of lime. The specimens analysed will be found in the state collection.

No.	Carbonate of Lime.	Silica and Alumina.	Carbonate of Magnesia.	Peroxide of Iron.	Water of Absorption.	Locality.
154	6.3	80.0	slight precip.	12.4	2.3	Chicopee Factory, Springfield.
155	4.8	83.2	slight precip.	11.0	1.0	Springfield, Lower Water Shops.
156	8.0	71.6	0.4	19.0	1.0	West Springfield.

The amount of calcareous matter in this diluvium appears small, when compared with that in the Berkshire marls. And I presume it will not be found valuable enough as a manure to be transported a great distance. But it ought to be recollected, that it needs only a small quantity of lime in a soil to work wonders upon vegetation. And further, it happens that in the immediate vicinity of nearly every bed of this substance, is a great deal of that sterile sandy land, which most needs a coating of marly clay, which is in fact the character of the calcareous diluvium. The large quantity of peroxide of iron which it contains, will probably also be useful on such a soil. And where this substance can be carted directly upon such fields, I cannot doubt, but they might be made permanently fertile without great expense. I trust that some of the farmers in the vicinity of this diluvium, will at least be tempted to try a few square rods of sandy land in this manner; and then they can judge whether its more extensive application may not be profitable. Who knows, but this substance, which has hitherto been regarded as a sign of utter barrenness, and employed only for mending roads, may at some future day spread fertility over many a field now scarcely worth cultivation!

I ought to remark, that in many places, beds of this diluvium occur which contain little or no calcareous matter, because the rocks

from which they were derived, contain none. Hence in using this substance upon soils, none ought to be employed which does not effervesce with vinegar, or other acids. By omitting this precaution, an experiment may fail, which would otherwise succeed.

5. Limestones in Massachusetts.

Such is the general deficiency of calcareous matter in Massachusetts, and so important is it in a variety of arts besides agriculture, that it seems desirable to ascertain the exact value of all the varieties of carbonate of lime within our limits. Besides the rich and pure limestones of Berkshire County, we have a large number of beds of this substance more or less pure, in various parts of the state ; and I have thought it desirable to analyse specimens from every bed of consequence. The following table exhibits the results which I have obtained. Some of the specimens were formerly placed in the state collection ; and those discovered since that collection was made up, are forwarded herewith.

Number.	Locality.	Sp. Gravity.	Carbonate of Lime.	Carbonate of Magnesia.	Carbonate of Iron.	Silica and Alumina.	Per cent of Quicklime.
429 of State Collection, .	North Adams—Crystalline, white, ...	2.74	99.6		trace	0.4	55.78
432 do . .	Lanesborough—White Marble, ...	2.69	99.4		trace	0.6	55.66
437 do . .	do Grey Marble, ...	2.76	93.2	5.5	0 88	0.3	52.26
433 do . .	New Ashford—Flexible White Marble, . .	2.68	81.5	16.2	0.88	1.4	45.65
436 do . .	Sheffield—Granular Dolomite, .	2.84	58.4	40.4		1.2	32.70
485 do . .	Bolton—Crystalline, ...	2.80	61.8	27.0		1.2	34.61
491 do . .	Chelmsford—Crystalline, ...	2.85	56.28	39.2	1.32	3.2	31.52
470 do . .	Bernardston—Crystalline, ...	2.72	98.1		0.90	1.0	54.94
211 do . .	W. Springfield—Fetid, Paine's Quarry, . .	2.73	93.48	0.9		5.6	52.35
459 do . .	Whately—Grey, Micaceous, ...	2.72	66.0			34.0	36.97
463 do . .	South Hampton—Micaceous, Grey, ...	2.93	38.4			61.6	21.50
496 do . .	Stoneham—White Compact, ...	2.84	58.84	15.6	1.76	23.8	32.95
494 do . .	Walpole—Grey, Granular, ...	2.80	70.3			29.7	39.37
184 New Specimen, .	Attleborough—Compact Grey, ...	2.71	94.6			5.4	52.98
185 do . . .	Springfield—Chicopee, Compact Ferruginous, .	2.74	44.8	26.6	8.2	20.4	25.08
188 do . . .	Norwich—Micaceous, Grey, ...	2.79	53.8			46.2	30.13
191 do . . .	Springfield—Chicopee, Fetid, Grey, . . .	2.73	86.8			13.2	48.61
192 do . . .	Sheffield—White Crystalline,—Girard College Quarry,	2.75	97.8			2.2	54.77
195 do . . .	Egremont—White Marble, ...	2.69	92.8	1.2		6.0	51.97
202 do . . .	West Natick—Grey Crystalline, ...	2.75	72.1	7.5		20.4	40.38
206 do . . .	do Compact, Yellowish, ...	2.68	54.2	0.6		45.2	30.35
203 do . . .	Claystone—Hadley, ...		56.6			43.4	31.70
204 do . . .	do North Adams, ...	2.60	53.6	1.2		45.2	30.02
205 do . . .	do West Springfield, ...	2.68	48.4			51.6	27.10

New localities of Limestone.

The localities of the limestones in the preceding table, of which specimens have been heretofore deposited in the State collection, will need no further description. But several of the specimens were obtained from new localities, and these will require a few descriptive remarks.

One is marked from Attleborough. I found a bed of it several inches, and perhaps several feet (for it is partly concealed) in thickness, on land of Thomas Arnold, in the southwest part of the town, near what is called the City. The rock there, is a remarkable variety of blood red greywacke conglomerate; and in the stone walls I noticed frequently a mixture of limestone. Hence I anticipate that probably beds of limestone thick enough to be worked may be discovered. It will be seen from the above table, that it is a quite pure carbonate of lime; and being often intermixed with the red slate, it would form when polished, a beautiful marble, if masses large enough can be obtained.

Two specimens given in the table are from the bed of the Chicopee River, at the Chicopee Factory Village, in Springfield. The first (No. 185) occurs abundantly all along that river in nodules, from half an inch to a foot in diameter, which, when broken, often show numerous seams filled with calcareous spar, and constituting what in Europe is called *Septaria*. This limestone also exists along that river, and especially in the bed and banks of Agawam river, in West Springfield, in layers several inches thick; which having the general reddish appearance of the rock, is not suspected to be limestone. Yet if I mistake not, this limestone will prove a very valuable material for preparing the Roman or water-proof cement. I strongly suspect that the fetid limestone of West Springfield, which is now used, is much less adapted for this purpose than the ferruginous limestone under consideration; and the chemical analysis of the two varieties confirms me in this opinion. For the former is almost a pure limestone, whereas the latter abounds in alumina and iron; which are very important in this kind of mortar: and it is well known, that the septaria of Europe is employed for this purpose.

The specimen of fetid limestone (No. 191) from Chicopee Factory Village, scarcely differs from that used in West Springfield, at Paine's quarry. It abounds in the bed of the stream at Chicopee Factory: though in general it is not so highly charged with lime as the specimen analysed. I doubt not but it would answer well in agriculture, if it be not needed for water proof cement.

The specimen No. 188, was sent me from the east part of Norwich, where it is said to abound. It is a variety of the micaceous limestone, so common on the west side of Connecticut River in a large number of towns. The analysis shows a rather too small proportion of carbonate of lime to render it very profitable to burn for common mortar unless the price of wood be quite low. It contains, however, rather more than 50 per cent of carbonate of lime, and in England it is a rule that limestone may be advantageously burnt that contains more than half of calcareous matter. As I have not visited the locality, I cannot say whether richer specimens may not be found there.

The specimen from Southampton (No. 463 of the State collection,) is of the same description, but containing still less of lime; too little, indeed, to be burnt for mortar. That from Whately (No. 459 of the State collection) is the best of this sort of limestone that I have found in any place; and situated very favorably for burning and transportation. Indeed, since my former report was finished a company have erected a lime kiln there, which has been several times filled and burnt with as encouraging success as could be expected in a new enterprise. They undertook it chiefly for agricultural purposes but the lime is found to answer tolerably well for laying brick and plastering. It requires, of course, less sand than purer limestone; and does not harden so soon as some kinds of lime; but at length it becomes unusually solid. When the value of this limestone shall be more fully appreciated, I predict that it will come into use, not merely in Whately, but also in many other towns where it occurs; as in Conway, Ashfield, Buckland, Charlemont, Heath, Colraine, Leyden, Williamsburgh, Goshen, &c. Indeed, I learn that a kiln of it has been burnt in Buckland and used on land with good success.

Berkshire Limestones.

It is gratifying to find, that as the demand for the rich and enduring marbles of Berkshire increases, new and extensive quarries are opened; which prove that it is doubtful even yet, whether others still better than any now wrought, may not yet be discovered. Indeed, when passing over that limestone region, and noticing the quarries, I have often been unable to see, except in the necessity of beginning somewhere, why a particular spot was selected for the excavation, in preference to a dozen others equally promising. In North Adams, on Hudson Brook, a little north of the village, and near the remarkable gorge and natural bridge, a quarry has been recently opened, which furnishes the most highly chrystalline and the purest limestone in the State. By the analysis above given, it appears that it contains less than one per cent of foreign matter. It will of course form a very white and enduring marble : though its highly chrystalline character, may detract somewhat from its elegance. The quarry is inexhaustible.

Another new quarry I noticed two and a half miles west of the village of Pittsfield. This also is inexhaustible, and though the rock is not as white as in some other places, it produces a substantial and valuable marble.

But a visit to the quarry in Sheffield, two miles north of the village, from which marble is now being got out for the Girard College in Philadelphia, will give one perhaps the best idea of the value and extent of the Berkshire marbles; and at the same time of the power which the arts give to man over nature. The rock (No. 192) is no better than in many other places; perhaps inferior to some other varieties—but to see masses more than 50 feet long, and 6 or 8 feet thick, split out by the apparently feeble means employed, makes a strong impression on the mind, and recalls the history of the enormous blocks of stone quarried and removed by the pyramid builders of antiquity.

The celebrated quarries in West Stockbridge still continue to be wrought and in increased quantity. And when the two rail-roads that will here intersect, and connect this point with Boston harbor and

Long Island Sound, shall be completed, we may expect that the demand for this marble, as well as for that from other parts of Berkshire, will increase. These marbles have long been justly considered as among the best for elegance and durability which our country produces; and I have no fears that their high character will suffer by being more extensively known and tested.

There is, however, a considerable difference among these marbles in their durability and power of resisting change from the action of the air, heat, cold and moisture. And it would be very desirable to be able from inspection, to decide which are the best in this respect. I had hoped in this report, to make some remarks on this subject: but do not feel yet prepared. I cannot but fear, however, that no tests which chemistry affords, will ever supersede the necessity of actual trial. It often happens, however, that where a new quarry is opened, fragments of the rock lie scattered on the surface, which have for a long time been exposed to atmospheric agencies: and from the greater or less disintegration which these have suffered, some conjecture can be formed respecting the rock proposed to be quarried.*

Magnesian Limestone in Agriculture.

Very many limestones contain magnesia, and it seems to be generally admitted, that where this is the case, a large quantity spread upon soil is injurious; that is, when the stone has been burnt so as to drive off the carbonic acid. In small quantities, however, it would seem that even calcined magnesia is useful; as we might presume it would be from the fact that most soils contain it in small quantity. Again, it appears probable, that magnesian limestone, if not burnt, but merely reduced to a fine powder, will operate favorably: or even if we admit that in such a case the magnesia exerts no action, it will not prevent the salutary action of the lime united with it. But since

* Through the liberality of several gentlemen who have the direction of the marble quarries in Berkshire, and the obliging intervention of H. W. Bishop, Esq., I have the promise of specimens of all the important varieties of marble in the county. As soon as they are received, they will be deposited in the State Collection, with the names of the donors: and those gentlemen who wish to procure marbles, can make their selection, without the trouble of a journey to Berkshire.

magnesia unites with geic acid and forms a compound more soluble in water than geate of lime, there is reason to believe that magnesia, properly applied, may be of service in agriculture. It would be very desirable that some experiments should be made upon this subject: for it will be seen by the analysis of our limestones that has been given, that many of them are magnesian. In the southern part of Berkshire county, the real dolomite, which contains 40 per cent of magnesia, is common; and it occurs in smaller quantity in many of the limestones of that county. Nor is it easy by the eye to determine whether a limestone be magnesian. The dolomite, however, is very liable to disintegration, and hence it is easily reduced to powder; and from the principles above suggested, I infer that this is the proper way to prepare magnesian limestone for agricultural purposes. Indeed, I would extend the remark to all limestones where fuel is not abundant. For the great object of burning lime, so far as its application to soils is concerned, is to reduce it to powder. Indeed, when applied in the state of quicklime it is very apt to prove injurious, like magnesia, until it has absorbed carbonic acid from the atmosphere: that is, until it is brought back to the state in which it was before burning. The inhabitants of Berkshire county will probably never need to use magnesian limestone for agriculture, or any other purpose, because they have enough that is free from magnesia. But much of their dolomite might be more easily reduced to powder than any limestone could be burnt. And if this suggestion about pounding and grinding limestone be of no importance in respect to that which contains magnesia, it may be of consequence in regard to that great quantity of fragments of pure white limestone, which are necessarily accumulated at the quarries, and which are now entirely wasted. How little additional labor would it require, by means of water power, to bring these into the state of powder admirably fitted for agriculture! and who can doubt, but this might become an article of exportation, when the contemplated rail-roads are completed, and the value of lime upon land shall be as much appreciated in this country as it is in Europe!

Limestones in the Eastern part of the State.

These remarks will apply with still greater force to the limestones in the eastern part of the State, than to those of Berkshire: first, because fuel is much more scarce in the vicinity of the sea-board, and secondly, because, as appears from the analysis that has been given, most of the limestones in that region contain magnesia, in such quantity that it would be desirable to have them pulverised rather than burnt for agriculture. The amount of magnesia in these limestones, is, indeed, greater than we could have anticipated, especially at Bolton and Chelmsford; and I regret that I have not time to repeat their analysis. Still from the fact that these limestones have been powerfully acted upon by heat from the surrounding unstratified rocks, we should expect magnesia in them. These limestones also, from having been melted, and containing more siliceous matter, will be more difficult to be brought into the state of powder by mechanical agency. Yet since, on account of the high price of fuel, but little lime is burnt at these quarries, it certainly deserves consideration whether water power may not be profitably applied to bring them into a state of powder, by some of the machines that are described in agricultural works for this purpose.

The locality from which the two specimens given in the preceding table as from Natick, I have not visited: since it was only a few weeks ago that I was made acquainted with the existence of limestone there. It was brought to my knowledge by Chester Adams, Esq., who says that the bed from which No. 202 was taken, lies three quarters of a mile N. E. of the Worcester and Boston Rail-road Depot, and was opened and some of it burned, during the revolutionary war, but was subsequently abandoned; not on account of its quality, but from the high price of fuel, and the low price of lime in the market. He says, also, that one gentleman has ground it for manure. The other specimen (No. 206) of a yellowish color and compact, was blasted from the rail-road, not far from the locality above named, where it was found in considerable quantity. The analysis shows that this variety contains a larger proportion of silice-

ous and aluminous matter. I am indebted for the specimens in the collection to Mr. Daniel Adams, Jr., of Amherst college.

The three last specimens whose analysis is given in the table (Nos. 203, 204, 205) are those singular concretions occurring in our beds of clay and usually called *claystones*. Probably they will never be of much benefit to the agriculturist, because it is doubtful whether they occur any where in sufficient quantity to be employed upon land. In a scientific point of view, however, they possess a good deal of interest, and if abundant enough any where, they may be used as limestone; for it appears that they all contain more than 50 per cent of carbonate of lime.

A good many other varieties of limestone might have been analysed from Berkshire: but I have intended to select the most important. In other parts of the State I know of a few limited beds, which are of so little consequence, that I have neglected them.* And from what I have given, I think the Government will be able to form a fair estimate of the extent and value of this most important article in the State. Had the vast beds of it in Berkshire county been spread over the whole State, or could they, by any mode of conveyance, be thus diffused, the supply for every purpose of architecture, mortar, and agriculture, would be abundant. And I doubt not but ere long this will happen to some extent. But without some such means, the supply in other parts of the State is scanty. I have, therefore, searched anxiously for other substances, that might answer, at least to a good degree, as a substitute for lime in agriculture. I have met with some success: and I have a hope that, if experiments should be tried upon some substances which I shall now proceed to point out, they will be found of importance.

6. Green Sand.

This substance constitutes a large part of what in New Jersey goes by the name of marl; and which, within a few years past, has wrought such wonders in some parts of that State. It is found also in Virginia, and probably may be found in all the southern States,

* I did not happen to have any specimen from the numerous limestone beds in Newbury.

that extend to the Atlantic. In my former report I described this substance as forming a bed of considerable thickness at Gay Head, forming a part of the tertiary formation there. I also intimated in the same place, that probably it existed on the continent at Duxbury. This point I determined if possible to settle during the last summer, and proceeded to Duxbury accordingly. And in the extreme north-westerly part of the town, or rather for the most part within the bounds of Marshfield, about two miles southwest from the seat of Hon. Daniel Webster, I found the spot described by Rev. Mr. Kent, as given in my former report. I was surprised to find the region abound in low hills of granite, with occasionally a swamp or small stream, being in fact, as unpromising a spot for green sand as I had seen in the State. Yet here I found that the green sand had been thrown up from at least three wells; one of which (on widow Sprague's place,) is in Duxbury, and the other two in Marshfield, near a small stream called South River. In the well on Mr. Kent's farm, (that described in my former report as in Duxbury,) the green sand was struck at the depth of 13 feet from the surface. In the other, that on the farm of John Chandler, Jr., it was struck at the depth of 21 feet; and the bed was five feet thick. This spot was nearly 20 feet above South River; and it occurred to me that perhaps on the margin of the stream the sand might be found, just beneath the surface. I caused an excavation to be made there, and after passing through one foot and a half of black mud, and the same distance through yellow sand and gravel very much consolidated, I had the pleasure of reaching the green sand. This spot is perhaps 15 or 20 feet above tide water. An extensive swamp extends from this place through the west part of Duxbury several miles, and I have reason to suppose the green sand may be found along its whole extent. Indeed, I strongly suspect that it may be found abundantly along the coast from Marshfield to Plymouth, and not improbably also on Cape Cod. The general aspect of a large part of Plymouth and Barnstable counties is very much like the region where this substance occurs.

The coloring matter of this sand forms but a small proportion of the whole mass wherever it has yet been found; yet it imparts a decided green tinge to the whole. The specimens which I ob-

tained at Marshfield, however, contained probably much less than the average quantity of the green matter. For some of it had been exposed to the action of rain, &c, for several years; having been formerly thrown out of a well; and that from the excavation which I made, was obtained only a few inches below the upper part of the bed. The specimen in the state collection, (No. 158,) bears a stronger resemblance to the green sand found on the continent of Europe, than to that from New Jersey. It became a point of much importance to identify this with other green sands. This could be done only by chemistry: and I am happy to be able to present here the very accurate results of analysis, which Dr. S. L. Dana, at my request has obtained, whereby the identity of this green sand with those of Europe, is completely established.

"The *green sand* from Marshfield," says he, "was treated as follows to separate the green particles. Washed in a large volume of water, the black, brown, and green particles subside, mixed with many quartzy grains. The grains form about one half the whole bulk. These grains were then washed in a smaller quantity of water, and the attrition caused the water, at each successive washing, to become ochrey, and I began to think that I should wash nearly all away.* I then treated the grains with dilute muriatic acid—washed them anew, dried and passed them through a sieve. The whole looked like mustard seed, with a few light green particles here and there among the black, green, and brown particles of quartzy grains. Pulverised, the whole becomes ochre brown. It was dried at 212°, and the analysis conducted as usual, gave—

Water	6.50
Black oxide Iron (ferroso-ferrique of Berzelius,)	64.944
Alumina	4.372
Silex	23.0
Lime	0.536
Magnesia	0.648
	100.

* The specimen which I sent Dr. Dana, had probably lain upon the surface of the ground for several years, and the iron had most likely become somewhat peroxidized."

"The earths, if silicates, will require 4.721 silex; and on no supposition will the remaining silex and water convert the iron into a hydrated silicate. Hence the iron is not combined with the silex, but exists as a hydrated oxide of iron. The composition will then be; free silex, 18.289; hydrated oxides of iron, 71.444; silicates of $\frac{\text{alumina, } 4.372}{\text{silex, } 3.886} + \text{of } \frac{\text{lime, } .535}{\text{silex, } .316} + \frac{\text{magnesia, } .648}{\text{silex, } .519} = 10.277.$ If we allow the hydrated iron to be mixed, a portion with the above silicates, except the lime, which Berthier and Turner did not find essential in their analyses of the coloring matter of green sand, we have a small portion of this coloring matter mixed with a large portion of hydrated oxide of iron. Only about 5 per cent of the whole is green sand, similar in its composition to that examined by the late Professor Turner, as stated in Dr. Fitton's "Remarks on the Strata below the chalk, &c., in the south east of England;" p. 108.

In a subsequent letter, Dr. Dana gives the result of his analysis of the green sand from Gay Head, of which No. 72 in the state collection, in the rooms of the Boston Natural History Society, is an example. This gives a better idea of the ordinary appearance of this substance than the specimen from Marshfield.

"I have finished the Vineyard green sand. It is very near the results of Turner. I washed the whole in water, poured off the light part, washed the remainder repeatedly, reserving the washing, which let fall a fine powder of a decided green tinge, feeling, when dry, under the pestle, like soapstone powder. The residuary quartzy grains were rejected, a few fine green particles among them. The second portion alone, was taken as the best sample of coloring matter, and gave—

Water	7.000
Silica	56.700
Alumina	13.320
Oxide of Iron	20.100
Lime	1.621
Magnesia	1.176
Manganese, traces, and loss	0.080
	100.

"The water and iron are nearly the same, the alumina the mean, and the silica about 6 per cent more, than the analysis of Turner and Berthier. No doubt therefore it is a true green sand."

The above analyses do not give the actual per cent of this green substance in the soil where it is found, though it evidently cannot form a large proportion. But this is not necessary in order that very decidedly good effects should result from its use in agriculture. The following extract from the report of Professor Henry D. Rogers, on the Geology of New Jersey, bears on this point as well as upon the general value of green sand in the cultivation of the soil.

"When we behold," says he, "a luxuriant harvest gathered from fields where the soil originally was nothing but sand, and find it all due to the use of a mineral sparsely disseminated in the sandy beach of the ocean, we must look with exulting admiration upon the benefits upon vegetation, conferred by a few scattered granules of this unique and peculiar substance. The small amount of green sand dispersed through the common sand, is able, as we behold, to effect immeasurable benefits in spite of a great predominance of the other material which we are taught to regard as by itself so generally prejudicial to fertility. This ought to exhibit an encouraging picture to those districts not directly within the limits of the marl tract, where some of the strata possess the green substance in sensible proportion. It expands most materially the limits of the territory where marling may be introduced and points to many beds as fertilizing, which otherwise would be deemed wholly inefficacious."

In another place of his most valuable Report, Prof. Rogers says, that "Mr. Woolley manured a piece of land in the proportion of two hundred loads of good stable manure to the acre, applying upon an adjacent tract of the same soil his marl in the ratio of about twenty loads per acre. The crops, which were timothy and clover, were much the heaviest upon the section which had received the marl, and there was this additional fact greatly in favor of the fossil manure over the putrescent one, that the soil enriched by it was also entirely *free of weeds*, while the stable manure had rendered its own crop very foul." Placing the home value of the farm yard manure at one hundred cents for each two horse load, and that of the marl at twenty-five cents per load, we have the expense of manuring one acre 200 dol-

lars, of marling the same 5 dollars." "Land which had been sold at 2½ dollars per acre, in consequence of the permanent increase in its fertility from the marl, is now worth 37 dollars the acre."

There is one fact, however, that will throw a doubt over the probable utility of this substance in Massachusetts. By taking the average of eight very accurate analyses of the New Jersey green sand, as given by Prof. Rogers, we find that it contains 10 per cent of potassa. Mr. Seybert's analysis gave nearly the same amount, and Mr. A. A. Hayes informs me that in two varieties analysed by himself, he found 7 per cent of dry oxide of potassium. But only a trace of potassa was found by Dr. Dana in the Massachusetts green sand, which, in this respect, compares with the English green sand analysed by Prof. Turner. Now Prof. H. D. Rogers imputes the value of this substance in agriculture almost exclusively to the potassa which it contains; and no chemist will doubt but that this ingredient will exert a very salutary influence upon soil. Yet there are other ingredients in the green sand, which some will suppose may increase its fertilizing power. One of these is the protoxide of iron, whose quantity is large, and which Prof. William B. Rogers, of Virginia, supposes may be of service, by its alkaline character, upon vegetation. This view will receive confirmation by some facts and reasonings that will be presented when I come shortly to speak of the application of clay in agriculture. It is probable, also, that the lime and magnesia in the Massachusetts green sand, may aid in a similar way. That all the good effects of this substance upon soil in New Jersey cannot be imputed to the potassa, seems probable, from the fact that granite and gneiss contain quite as large a proportion of potassa, and when spread in a powdered or decomposing state upon the soil, ought, therefore, to fertilize as much as the green sand; especially as Mr. Hayes informs me that the New Jersey green sand "decomposes in nitric acid slowly, being less soluble than some feldspars." But there is no evidence that the good effects of the granite and gneiss are as great as those of the green sand; and hence we must call in the aid of some other ingredient to explain its fertilizing power.

I do not, therefore, despair of our green sand in agriculture. It certainly deserves a fair trial, when we consider what a change this

substance is producing in much of the poorest land in New Jersey and Virginia. It would be very easy to obtain an abundance of it at Gay Head, where it occurs in great quantities, towards the north end of the cliff. Or I doubt not but it may be found in many places along the coast in Barnstable and Plymouth counties, a few feet beneath the surface, in the lowest places. Very likely a little research may bring to light varieties that contain potassa; and should this be the case, the change that might thereby be produced in the agriculture of the south-east part of Massachusetts, can hardly be calculated.

7. Clay in Agriculture.

There is abundant evidence that our common clays are of great value when spread upon land. I find that they have been used to a considerable extent in the state; so commonly, indeed, that I abandoned the idea I had formed of giving a detailed account of particular instances. So far as my inquiries have extended, the testimony is decided that our blue clays exert a very favorable effect upon the soil. When spread upon sandy ground we might expect that they would render it a better resevoir for salts and geine. But thoroughly to ameliorate our sandy soils in this way, requires far more clay than is usually employed, and I am perfectly convinced that they exert other than a mechanical influence; that in fact, their effect is analogous to that of lime. I refer here to the blue clays which are far the most common. As to the white clay I have not learnt its effect upon the soil; but from the fertility of some of the soils in Kingston, Plymouth, and Barnstable, where white clay is mixed naturally with sand, I presume this sort is equally valuable with the blue.

In view of the wide extent of our beds of clay, and the use that might be made of it upon land, I felt desirous to ascertain to what principle it owes its fertilizing powers; and therefore subjected a few specimens to analysis in the ordinary way by solution in alkali. The following are the results. I omit however certain white clays, which I found destitute of iron, and therefore probably not very likely to be of much value upon land. But for other purposes, of which I shall speak shortly, they are of a good deal of importance.

Analysis in the Dry way by Alkali.

No.	Locality.	Water and Organic Matter.	Silica.	Alumina.	Prot-oxide of Iron.	Oxide of Manganese.	Lime.	Magnesia.	Sulphur and Loss.
139	Northfield; blue. . .	10.8	46.93	28.[illegible]7	9.9			0.1	2.9
140	Sunderland; light blue.	8.2	49.00	29.15	13.1	0.15	slight precip.	0.4	
142	Kingston; white. . .	3.5	71.00	16.30	7.3	0.30	do	0.3	1.3
143	Lowell; white. . .	4.0	61.52	20.50	9.2	0.56	0.56	0.44	3.22

I tried some of our blue clays also, for geine ; but in general they yielded only very little, and perhaps none. For so strongly do they retain water, that not improbably all the loss, especially of soluble geine, might have been imputed to this substance, which had not been all expelled by a heat of 300° F. ; and then the peroxidation of the iron by ignition, renders this method of analysis quite uncertain. I, therefore, omit the results ; only observing, that the amount of sulphate and phosphate of lime obtained, was about the same as in good soils. I therefore suspect that we must impute most of the good effects of clay as a manure to the large quantity of iron which it contains. On this point, however, I will present some suggestions of Dr. Dana, with which he has kindly favored me.

"If we attempt," says he, "to account for the action of *clay*, independent of its amending a sandy soil, we should bear in mind that all our common clays contain more or less of sulphuret of iron. The conversion of this into the persulphate of iron is the natural consequence of exposure : free sulphuric acid then results, which acts on any lime in the soil, forming sulphate of lime : (the Gay Head crystals of sulphate of lime are so formed:) so that by spreading clay, we spread plaster. The iron in clay also plays its part thus. It is evident from Chaptal's experiments, that protoxide of iron is not beneficial in agriculture. He attributes this to the oxidation of the iron, depriving the plant of its intended oxygen. Nature is no niggard ; nor is the reason of Chaptal very philosophical. We have

seen above that protoxide of iron does not act on geine. Now by exposure, the protoxide becomes peroxide; and then, I conceive begins an action similar to that of lime. If the free sulphuric acid, produced as we have supposed, finds not lime enough, it will decompose all earthy geates, and thus a fresh portion of nutriment is set at liberty. Both the effects of clay—the production of plaster and the formation of peroxide of iron, are speedily produced by burning the clay, as is often practised."*

Still more recently, Dr. Dana adds the following: "Some facts have lately come under my eye, and have recalled others to mind, which I have followed up experimentally; all tending to show, *that if iron peroxidates itself in contact with vegetable fibre, the texture of the vegetable fibre is weakened*, and geine is produced, and that *in a few hours. It is during the passage from protoxide to peroxide that the 'saponifying' action takes place*, geine is produced, and then *combines with peroxide.*"

In the few analyses which I have given above of our clays, I have considered all the iron in them as existing in the state of protoxide; although I made no attempt to ascertain whether some of it might not be a peroxide. Very probably this may to some extent be the case: especially where the clay has a yellowish tinge. Yet for the most part, I doubt not it is a protoxide. A slight error here cannot affect the reasoning above presented.

I hope our farmers will make more numerous and accurate experiments upon the use of clay as a manure; not merely upon sandy land, but following the suggestions of Dr. Dana, upon other soils, in the expectation that its action will be analogous to that of lime. Pro-

* The agency of geine in the fermentation of manure is thus explained by Dr. Dana with his usual clearness and felicity.

"By fermenting dung vast volumes of ammonia are liberated. I do not think that it is the action of gases as such, which we want or which nature intends as food of plants to be derived from the soil. The air is always full of all which this fermenting manure can supply in a gaseous form. The true actions of ammonia and carbonic acid resolve into their effects on geine. The ammonia combines as alkali with that, and thus it becomes very soluble, and the carbonic acid produces sur-salts of the earthy geates of lime and magnesia. It is these, liberated the moment the plant demands them, which cause all the geine of the manure to become alcaline soluble geates."

"How wide is the influence of geine! It not only enters by itself into the food of vegetables but becomes the very solvent which nature has proposed to act on the alcaline earths and oxides, dissolving them as they are liberated from decomposing granitic sand."

bably, the best clay for this purpose occurs in the valley of the Connecticut river; but it abounds in almost every part of the state, and perhaps it may in a good measure supply the deficiency of lime. It will of course require to be laid on in much greater quantity than marl, and probably, as in the case of marl, too much may be used. How much ought to be used is a fair subject for experiment.

8. Decomposing Feldspathic and Micaceous Rocks.

Feldspar and mica contain quite a large proportion of potassa; a substance well known to be valuable in agriculture. And these minerals constitute a large proportion of several of our most common rocks, such as granite, sienite, greenstone, porphyry, gneiss, mica slate, and graywacke. Hence we might predict that these rocks, recently decomposed or reduced to fine powder, would form a good dressing for land; especially when we recollect that the same rocks contain a fair proportion of iron. Now some varieties of them are very liable to decomposition: and when partially crumbled down, if ground in a plaster mill, they will be brought into a proper state for such a use. These suggestions, however, are more the result of theory than of actual experiment: although such a use of powdered rock has sometimes been made and found of value. Indeed, an example of the good effects of decomposing gneiss upon cultivation was pointed out to me in the south part of Athol: and No. 100 presents a specimen of this substance, obtained nearly a foot from the surface in a ploughed field, but not below the point to which geine had penetrated; as appears from the analysis. Yet as this is insoluble it could not affect the vegetation but slightly. The salts of lime also are not in large proportion, and very probably its good effects, which were not represented as great, may have chiefly resulted from the liberation of potassa from the mica and feldspar.

Now there is a great deal of partially decomposed rock in the formations of this State, which have been named above, and they constitute at present the most barren spots in our soils: because they are not reduced fine enough to form a good soil; or because they are too strongly impregnated with stimulating salts. Perhaps if spread over soils already containing geine, they might operate favorably up-

on crops. At least, it seems to me there is so much plausibility in the theoretical suggestions above made, that it would be desirable to make this experiment on a small scale, since it is so easy, even if it be necessary to reduce the crumbling rock to powder in a mill.

9. Hydrate of Silica.

In describing our marls I have already given some account of this peculiar substance. In its purest state, as it exists in No. 157 from Spencer, it is difficult to distinguish it, except by chemical tests, from carbonate of magnesia, which it exceedingly resembles in its color, levity and taste. When mixed with some vegetable matter, as in Nos. 169, 170, 171 from Barre, Andover, and West Bridgewater, its color is darker. It occurs in many parts of the State in swamps, beneath peaty matter, especially in the extensive gneiss region of Worcester county. And as it has often been mistaken for marl, it has been frequently applied to land. I should not expect from its nature that any important effect, good or bad, would result from it; for in its pure state it is little else than a hydrate of silica; that is, water and silica, as the following analysis of No. 157 will show.

Water	10.00
Silica	86.46
Alumina	2.96
Oxide of Manganese	0.28
Magnesia	0.30
	100.00

I can hardly conceive, that this substance in a pure state should be of much use in agriculture; and yet I have had testimonies of such a character to its value, that there can be no doubt but it is a fertilizer of considerable importance, especially when obtained from beneath peat. It occurs abundantly in the State of Maine, as well as in most other parts of New England; and Dr. C. T. Jackson, the State Geologist of Maine, in a private letter remarks as follows: "It is a curious fact that this substance, so abundant under our peat bogs, acts as a fertilizer to dry soils. Its action, I suppose, is par-

tially due to its hygrometric properties, and partly to its imbibing the juices of peat. It does not contain any lime, but is a sort of siliceous marl, if I may so call it." *

Mr. Alonzo Gray, to whom I am indebted for the specimen from Andover, says: "I have found this substance in three places: in one of them on the surface, in the others beneath peat. One of the beds covers a surface of six acres. The peat upon the top is from 2 to 6 feet thick: then succeeds a vegetable substance mixed with some earthy deposite, from one to two feet, then the supposed marl, 15 feet in depth. The substance immediately under the marl is worth about one half as much as manure for land; and has been used considerably for that purpose. A small quantity of the substance under this was used on land the last year: but not in sufficient quantity to test its use. The gentleman who owns the land, has dug out a large quantity with the intention another year of giving it a fair trial." Probably the stratum which Mr. Gray describes as immediately under the peat, is a mixture of this hydrate of silica and geine derived from the peat; and hence its fertilizing effects. And I presume that wherever this hydrate is dug, that will be found best which lies nearest to the peat. I might mention other cases in which it has been successfully applied to land: but my principal object is to call the attention of our intelligent citizens to the substance. Its situation in swamps, its levity when dry, and its not effervescing with acids, will enable any one to distinguish it from analogous substances.†

* There has been great confusion in the use of the term marl, and doubtless it has often been applied to substances that contained no carbonate of lime; although its scientific use is now limited to a mixture of carbonate of lime and clay. We want very much a name for several substances, analogous to that described above. Why not call that friable substance in which silica predominates, *siliceous marl;* that in which clay predominates, *aluminous marl:* that in which iron predominates, *ferruginous marl:* that in which lime predominates, *calcareous marl,* and that in which green sand predominates, *green sand marl?*

† For the specimen, No. 170, from Barre, I am indebted to Mr. A. Jenkins, of that place: and for No. 171, from West Bridgewater, to John C. Howard, Esq., on whose farm it was found.

10. Sources of Geine or Vegetable Nutriment in Massachusetts.

Having now pointed out the situation and value, so far as known, of all the calcareous deposites in the State that can be applied to agriculture, and of other substances whose action on soils is somewhat analogous to that of lime, the next grand inquiry is, whether there are any sources in the earth from which additional quantities of geine can be obtained, or matters convertible into geine. I pass by the whole list of common manures, presuming that they will be fully discussed by the Agricultural Surveyor. And I shall merely notice the natural sources of vegetable nutriment within our limits.

Peat Swamps.

The peat swamps of New England have become a vast repository of organic matter, which is, and has been, for ages increasing. In addition to the larger vegetables, which, as they die, fall and are enveloped in the soft matter on which they grew, there is a thick mat of moss, which—especially the sphagnum—continues to flourish at the upper part while the lower part dies and decays. In favorable circumstances as to wet and temperature, this mass of vegetable matter becomes converted into peat. Only a small part, however, of what is thus accumulated, becomes peat of such a character that it answers well for fuel. Often it is too much mixed with mud to be easily burnt, and sometimes the vegetable fibre is scarcely changed. Yet the whole of it is capable of being converted into vegetable nutriment. And I am convinced, from all that I have seen and heard, that Massachusetts contains enough of this geine and vegetable fibre in her swamps, to render all her fields fertile for centuries. In other words, here is an exhaustless source of geine. Some of it is already in a soluble state; and therefore the black matter from swamps, is rarely spread upon soils without producing some benefit. Yet for the most part the geine is in such a state as to require some chemical change before it will become soluble nutriment, fit to be absorbed by roots. It is an important inquiry then, what is the best mode

of accomplishing this change. This has been attempted, first, by mixing the peaty matter with good manure in alternating layers, and suffering them to ferment for a long time, the peat being in much the greatest quantity. Secondly, by mixing it in a similar manner with lime; and thirdly, by mixing it with alkali, or some compound containing alkali. The principles respecting geine which have been advanced in this Report, will probably enable us to decide as to the preference to be given to any one of these methods. And here I have it in my power to give the opinion of Dr. Dana, whose remarks I am always happy to substitute for my own, on a subject with which he is so familiar, and which he has done so much to elucidate.

"The fact," says he, "that peat or turf is very soluble, in alkali, seems not to be known among our farmers. The usual practice of mixing lime with peat or turf is decidedly the worst which can be followed. The geine which constitutes a large part of peat bogs, forms with lime a compound little soluble in water, requiring at least 2000 parts of water to one of geate of lime: and if the compound has been dryed and sun-baked, a still larger portion of water is required: it becomes, in truth, almost insoluble. With alumina, geine forms a compound still more insoluble than with lime; and though the vegetable matter in combination with these earthy bases, is actually absorbed by the roots of growing plants, still the geine is in a state much less favorable than when in combination with alkali. Mix ley of wood ashes with peat, and we form a dark brown vegetable solution: the alkaline properties are completely neutralized by the geine, and very often ammonia escapes from turf when treated by caustic alkali. When we add, that this geine absorbs and retains nearly its own weight of water without seeming moist, it is evident, that with the use of ley or wood ashes, the value of peat as a manure will be very much increased."

I will only add, that in my opinion it would be very desirable to have a series of experiments performed by a practical chemist upon the different varieties of our peat, and especially upon the best mode of converting it into soluble geine. Since by the old methods of analysis the different varieties of peat would be found to differ from one another only in the quantity of organic matter which they contain,

I supposed it would be useless to analyse them, and therefore did not collect specimens of the peat and other vegetable matters that occur in our swamps. The doctrines respecting geine put a new aspect upon the case, and lead me to regret that such a collection was not made. The labor of doing it now, however, is small; and when it is considered what an immense mass of organic matter now lies useless in our swamps, while the fields around them yield but a scanty crop, and that the chief reason why our farmers make so limited a use of this manure, is, that they find it difficult to convert it into soluble nutriment, I sincerely hope that the government will do all in its power to bring into use this important part of our fossil resources.

Geic Compound. (Apothemite.)

On the farm of Col. Moulton, in the south-west part of Newbury, seven miles from Newburyport, occurs a peculiar substance, which, at first view, is pronounced to be a sort of peat; but, on applying heat, it is found to be something quite different. Its color is a deep brown, hardly to be distinguished, when in mass, from black. When wet, it is soft and unctuous, and exhibits some degree of elasticity; when sundried, it becomes quite hard, and receives a polish from hard substances. Before the blow-pipe, the coloring matter disappears and a white enamel is formed. From an accurate and very satisfactory analysis which Dr. Dana has made of this substance, it appears, so far as I know, to be a new and undescribed compound. His analysis is as follows:

Water,	13.500
Geine,	19.625
Silex,	36.908
Alumina,	19.197
Peroxide of Iron,	8.826
Sulphat of Lime,	1.542
Magnesia,	.402
Specific Gravity, 2.08	100.

" The earths and oxides," he remarks, " are such as we might expect from the decomposition of trap or greenstone: the geine, I

presume, has been gradually deposited from the solution of vegetable matter in water. It has precipitated chiefly in combination with peroxide of iron, forming *pergeate of iron.* The sulphate of lime is doubtless derived from vegetable decomposition. It enters largely into the composition of the grasses; and all our waters, whether of ponds, rivers, or springs, contain, so far as I have examined, traces of sulphate of lime. The black coloring matter, or geine, is readily soluble in carbonated or caustic alkali: and keeping this fact in view, I think that, mixed with wood ashes, the above substance will form a very valuable manure, particularly where the soil is light and sandy."

This geic compound at the locality above named, forms a layer from six to eight inches thick, and sometimes more, over several acres of a deep, basin-shaped cavity, which is nevertheless dry enough to plough. It did not seem to exert any fertilizing effect upon the soil in that place, but rather the reverse, though on this point I made no inquiries. But probably the geine is too strongly bound to the iron and alumina to be given up without the action of an alkali. Dr. Anthony Jones of Newburyport informs me, that he knows of two other places where this substance is found; one of which is on the north side of Merrimack river, in Amesbury. Indeed, there is every reason to believe, that it will be found in many places in Essex county, where sienite prevails, and it may, therefore, become an object of no small interest in agriculture.

The astonishing power of this substance to absorb water, may be learnt from the fact, that while it appears from the table that has been given, that 100 grains of no soil absorbed, in 24 hours, quite seven grains, 100 grains of this compound absorbed 19.1 grains. This fact shows us that the absorbing power of soils depends much more upon the quantity of geine which they contain, than upon any other ingredient.

Use of this Substance as a Paint.

This geic compound, with no other preparation than that of drying, has been employed as a paint, mixed with oil. It is said to answer a good purpose; and at Col. Moulton's I saw some wood-work cov-

ered with it, which appeared well. The color is so deep a brown that it passes very well for black.

It answers, also, as a water color, on paper. By simply grinding it in water and using it for a landscape, the color could hardly be distinguished from that called sepia. Through the kindness of John Tappan, Esq., of Boston, I obtained the following opinion respecting this substance, of a distinguished manufacturer of water colors in New York, to whom it was sent in a crude state, with no information respecting its nature or origin. By simply suspending it in water, it will be easy to obtain a much more delicate variety for the purpose of painting; and as it will probably be found of different shades of color at different localities, it may perhaps be an object to perform some experiments of this sort; for it may prove that it will be more valuable as a paint, than in agriculture.

"The sample of color," says the manufacturer, "which appears to be a variety of lignite, might probably be of some use, as a deep brown color, for common purposes; but does not appear to have any extraordinary richness or body. It is not sufficiently *brown*, for either sepia or cologne earth, (or vandyke brown), and it is too brown to be sold for black. But if it could be sold quite low, it might come into use for a brown black, or deep brown."

For this geic compound, which appears to be well characterised, Dr. Dana has suggested the appropriate name, *Apothemite :* apotheme being the term applied by Berzelius to a deposite of geine, &c. in vegetable solutions.

11. Substances yielding both Geine and Salts of Lime.

I shall delay for a short time upon two other substances, abundant in the state, which may be of no small use in improving our soils, by affording both geine and the salts of lime.

Marsh Mud.

Every intelligent farmer probably knows, that this substance forms an excellent manure; although I apprehend it is employed far less than its value demands. An intelligent farmer in Maryland states,

that he "deems it more valuable than barn-yard manure;" and that "it never failed in any application he had made of it." He also prefers it to marl, because "it is more accessible, its effects are quicker and much more can be done in the way of improvement for the same money." At the same time he confesses, that the permanent advantages of marl are much greater; and thinks that marl and marsh mud will both be improved by combination."* This last remark appears still more important, when we ascertain what it is that gives an agricultural value to this substance. The fact is, it sometimes contains a large quantity of geine, and sometimes but little, while the quantity of the salts of lime, soda, and magnesia, is rather large; so that sometimes a mixture of marl will be of service, and sometimes not. The following analysis of a few specimens of marsh mud, both in the ordinary way and by Dr. Dana's method, will show us, I think, what it is that constitutes its fertilizing power, and afford some useful hints as to its application.

Analysis in the dry way by Alkali.

No.	Locality.	Water of Absorption.	Organic Matter.	Silica.	Alumina.	Oxide of Iron.	Lime.	Magnesia.	Salts soluble in Water.	Sulphuretted Hydrogen & Loss.
135	Newburyport, . .	3.2	3.3	68.1	14.7	7.4	2.0	0.8	0.2	0.3
136	Medford, . . .	9.5	12.5	50.95	14.9	8.15	1.1	0.2	0.6	2.1

Analysis by Dr. Dana's Method.

No.	Locality.	Soluble Geine.	Insoluble Geine.	Sulphate of Lime.	Phosphate of Lime.	Granitic Sand.	Specific Gravity.
134	Cambridge, ...	13.0	7.4	2.3	0.4	76.9	1.92
135	Newburyport, ...	1.5	0.1	3.0	0.5	95.1	2.52
136	Medford, ...	7.5	5.6	2.6	0.3	84.0	1.92

* Farmer's Register, July 1834; p. 93.

A substance so rich in geine, or salts of lime and soda, or in both, as the above analyses show, cannot but prove a fertilizer of the soil if spread upon it. If a soil be quite poor, those varieties should probably be chosen that contain the most geine; and this can be judged of by their comparative lightness when dry; the lightest abounding most in organic matter. But if the soil already contain a good deal of inactive vegetable matter, the varieties that abound most in salts will probably be most efficacious; though an additional quantity of geine can do no harm, and may do much good. If marsh mud be applied at random, it is not strange that varieties of it, almost destitute of geine, should be sometimes put upon exhausted soil, and that no good effects should follow. Hence the necessity of some fixed principles to guide the farmer. And since Massachusetts contains so much sea board, and so much land near the coast that may be benefited by this substance, a correct mode of applying it is of great importance.

Muck Sand.

As this substance has never been proposed for use in agriculture, it will be necessary to state the circumstances that have led me to bring it forward in this place.

Nine or ten years ago, Luther Root, Esq., Cashier of Amherst Bank, had occasion to dig a well in his garden in Sunderland, where he then resided. This was only eighty rods from Connecticut river, and the land there is alluvial to the depth of more than twenty feet. Near the bottom the excavation passed through a thick stratum of what is usually called quicksand, and which on being thrown out emitted a strong odor of sulphuretted hydrogen. It not being convenient to remove all this earth, it was spread upon a considerable part of the garden, which was a good soil and always well manured. He was warned against doing this, lest it should ruin his garden, and he thinks the quantity spread was not greater than a good coat of manure. The part thus covered was mostly planted with watermelons and other vines: and, instead of injuring the spot, it produced so great an increase of fertility as to astonish himself and his neighbors, and to lead them to search the banks of the river and low places for

a similar substance. The good effects continued for two years, and afterwards declined, so that in a year or two the land thus treated was not better than the other parts of the garden.

Seventeen or eighteen years ago, Mr. Rufus Rice had occasion to dig a well on his farm in South Deerfield ; and after passing through six feet from the surface, he struck upon what he describes as quick-sand, though dry at the time he dug it, and probably mixed with clay. He represents the substance dug out when wet to be almost as much disposed to flow as water, and that it was very difficult so to wall up a well with stones that this sand would not pass through and fill it. He describes it also as giving out a strong odor, and a small quantity which he showed me, that had lain for fifteen years, still retained that odor, and appeared to be identical with the *muck sands* to be described in this Report. Wishing to remove the sand thus thrown from a well twenty-two feet deep, and having understood that the effect of a change of soil was good, he carted five loads, after it had lain exposed for a year, upon a piece of ploughing, spreading it about as thick as a good coat of manure. This was in the autumn ; and the next spring the whole piece was planted with Indian corn, after having been manured in the hill. But that part of the field, which had received the muck sand, soon began to show a much more thrifty growth than the other, and yielded a greater crop. From that time to the present, corn, oats and clover, have been the rotation of crops every three years, except that two crops of rye have been raised upon it, and whenever it was manured, all parts were spread over alike. And even up to the present time, the part on which the muck sand was spread, seventeen years ago, continues to show decidedly more fertility than the other part. I saw this difference last autumn in the crop of Indian corn then growing, and it was considerable.

A few rods from the spot where the well above noticed was dug, another had been excavated three years previously to the depth of eighty feet, and a large quantity of the muck sand, with perhaps some clay, lay upon the surface ; although the well itself had been filled by the caving of the sides. Mr. Rice carried from five to ten loads of this upon a spot of dry mowing, which had almost ceased to produce grass. It was spread about as thick as a good coat of manure, but with no mixture of manure, some time in June. On the

first crop of grass that year it produced no effect, and there was not enough grass to be worth gathering. But the second crop was a very heavy one, and consisted mainly of clover, although the clover had previously disappeared. The next year the first crop was equally good, the second not so large, though better than middling. In subsequent years the good effects became less and less obvious: but they were visible at least ten years.

The facts communicated to me by Mr. Root (those respecting Mr. Rice's experiments I did not learn till somewhat later) seemed to furnish a clue that might lead to results of considerable importance.

But the substance that produced such effects upon the soil had all disappeared from the surface, and could not be obtained from the wells. It occurred to me, however, that the same stratum must extend from Sunderland village to Connecticut river ; and that its outcrop might be found there, as the bank is more than twenty feet high. A gentleman acquainted with the substance accompanied me thither; and we soon found a stratum of sand several feet thick, which he recognized at once as identical with that dug from the well. Having seen it in one place, I was able to trace it in others. I examined the banks of Connecticut river across the whole state ; and wherever they are alluvial, I almost uniformly found this stratum from ten to twenty feet below the general surface. I traced it, also, in many places, in the banks of the Housatonic and Merrimack, the Deerfield and Westfield rivers, and indeed on almost every stream large enough to form much alluvial deposition. On the small streams its depth beneath the surface and its thickness are less. But its leading characters are alike, and somewhat peculiar : and as they made it easy for me to find the stratum, I think I can point them out so that others will be able to recognise it.

The specimens of this substance in the State Collection (Nos. 126, 127, 128, 129, 130, 131, 132, 133) convey but an imperfect idea of its appearance in its native situation, where it is almost always very wet, and generally exhibits a slightly greenish tinge, though perhaps this results from its mechanical rather than its chemical characters. In the banks of our streams, this stratum is the first one from the surface that arrests the water in its descent into the earth ; and hence water is seen oozing out from it in almost every place. It

frequently lies immediately above a stratum of gravel. It is also remarkable for its yielding nature when wet; it being easy to run a pole several feet into it, and unless covered with turf, a man in walking over it will sink into it several inches. The cause of its arresting water in its descent, and also of the extreme mobility of its particles among themselves, is probably chiefly dependent upon the fineness of its texture, and the form of its particles, rather than upon its chemical composition. When an attempt is made to dig into it with a spade, or trowel, it conducts very much like soft suet. And yet its composition is decidedly sandy: and therefore I call it *muck sand*, although it generally goes by the name of *quick sand.*

Another important character is, that when fresh dug, this substance almost invariably gives out the odor of sulphuretted hydrogen: that is, an odor considerably resembling that of a gun barrel which has been fired repeatedly with gunpowder. Very frequently, also, there is seen oozing from it a reddish matter of the color of iron rust, and which indeed is the oxide of iron, proceeding probably from the decomposition of the sulphuret of iron, whereby the sulphuretted hydrogen is produced. I am inclined to believe that the odor of the sulphuretted hydrogen is so connected with its fertilizing properties, that I doubt whether any sand, not giving it out, will prove efficacious.

It should also be mentioned, that vegetable matter, even sometimes in the state of vegetable fibre, is generally present in the muck sand. Indeed, it seems to be the only stratum, which I have found deep in the earth, that contains much organic matter. In short, it does not differ, so far as I can ascertain, from the rich deposites of mud and vegetable matter, that are now often formed by our streams at high water, except that it has been for a long period in the earth, and thus many important chemical changes have taken place in it, and it has also been the recipient of all the soluble matter, which has percolated from the strata above, but which this stratum has arrested.

These remarks will I trust not only enable others to identify this substance, but will form also the groundwork of a theory that will explain its fertilizing power. This, however, will be better understood when I shall have presented analyses of several specimens by both the methods described in this report.

Analysis by Alkali.

No.	Locality.	Water of Absorption.	Organic Matter.	Silica.	Alumina.	Oxide of Iron.	Lime.	Magnesia.	Salts soluble in Water.	Sulphuretted Hydrogen & Loss.
126	Sunderland,	3.8	3.5	64.01	15.03	12.04	0.10	1.16	0.10	0.26
130	Sheffield,	2.0	2.0	70.68	11.61	10.10	0.80	1.63	0.15	1.03
132	Amherst,	4.0	5.0	64.34	13.5	12.00	0.06	0.90	0.20	
133	Leominster,	1.5	0.5	73.31	14.25	8.14	1.00		0.10	1.2

I have been favored, also, with the following analysis of the muck sand (No. 129) from Hadley, by Dr. Dana.—100 grs. after ignition to drive off the water and organic matters, yielded

Silica, ...	71.008
Alumina, ...	16.706
Oxide of iron, ...	6.202
Lime, with some sulphate of lime, ,	3.336
Magnesia, ...	1.552
Traces of manganese and potassa, and loss,	1.196
	100.

Analysis by Dr. Dana's Method.

No.	Locality.	Soluble Geine.	Insoluble Geine.	Sulphate of Lime.	Phosphate of Lime.	Granitic Sand.	Specific Gravity.	Gain of 100 grs. in 24 h'rs after heating to 300°.	Propor'al Absorbing Power.
126	Sunderland, Ct. River,	2.1	3.0	1.0	0.9	93.0	2.57	2.1	42
127	Bradford, Merrimack Riv.	0.8	3.1	0.6	0.7	94.8	2.48	1.8	36
128	W. Springfield, Ct. Riv.	4.1	0.2	3.0		92.2	2.68	1.5	
129	Hadley, Fort River,	{ 2.9 { 3 09	3.2	1 4 2.25	0.3	92 2	2.60	1.9	38
130	Sheffield, Housatonic Riv.	1.0	2.1	1.9	0.2	94.8	2.63	1.4	28
131	Northfield, Ct. River,	1.9	1.8	1.2	0.2	94.9	2.46	1.0	20
132	Amherst, Fort River,	6.3	0.0	1.2	0.7	91.8	2.39		
133	Leominster,	0.4	2.3	1.0	0.5	95.8	2.68	0.4	8

It will be seen that in the case of the muck sand from Hadley, a double analysis is given. The latter was furnished by Dr. Dana, who did not obtain the insoluble geine, nor separate the phosphate of lime from the sulphate. I give both results, partly because it is the only example which I am able to present, in which my analysis by this new method can be compared with that of another individual.

The specific gravities given above show that in general the density of these muck sands is greater than most of our soils, as we might expect from the fact that they are very sandy. The two last columns show that their power of absorbing water is small; which result also we should expect for the same reason. I regret that my experiments upon the power of these muck sands to retain water, are as imperfect as upon the soils, since we should rather expect that this might be considerable and of some service in agriculture. So far as the trials which I have made enable me to judge, they favor this presumption, though they do not indicate any remarkable retaining power. Thus, on the 20th of January, 200 grs. of the following soils and muck sands, with 100 grs. of water added, were exposed three hours to the sun, from 11 to 2 o'clock, clear and wind westerly, and they lost as follows:

No.		Loss.	No.		Loss.
3	Alluvial Soil,	69.7 grs.	114	Sienite Soil,	54.4 grs.
4	do	69.4	115	do	66.8
5	do	70.0	116	do	57.6
6	do	68.7	118	do	61 0
7	do	71 6	119	do	63 6
15	Tertiary Argil.	66 7	121	Porphyry Soil,	66.3
16	do	69.2	123	Greenstone Soil,	64.4
18	do sandy,	78 8	127	Muck Sand,	50.0
20	do do	67.7	129	do	50 1
23	Sandstone Soil,	68.0	130	do	51.4
24	do	56 6	131	do	56.2
26	do	70.1	132	do	47.1
27	Graywacke Soil,	70.1	134	Marsh Mud,	51.0
30	do	56.3	135	do	52.9
31	do	55 8	136	do	51.9

From the water in which some of the muck sand from Sunderland had been boiled, pure ammonia, as well as carbonate of ammonia and phosphate of soda, threw down slight precipitates. Hence I infer

the existence of some soluble salt of magnesia, probably the sulphate. But in no other specimen did any such result follow the application of these tests. The proper tests, however, detected in them all sulphate of lime about in the same quantity as in most of the soils. Its amount may be seen in the table of analysis of the muck sands by alkali.

The preceding analyses appear to me to show that there is no single ingredient in these muck sands that will explain their fertilizing power. But there are several circumstances that probably conspire to such a result. Most of them contain a considerable amount of soluble geine, as well as of the sulphate and phosphate of lime; and I ought to remark in respect to some of them, that they were obtained in places which are exposed to the action of water a considerable part of the time, which may have abstracted a portion of the salts and the geine; as I took them from a few inches below the surface. This was the case with the specimens from Northfield, Bradford, and Sheffield. The others were obtained at a greater depth from the surface. That, for instance, from Amherst, which yielded so large a proportion of soluble geine, was taken from an excavation just made several feet deep. This circumstance should be kept in mind, if any of our farmers should think it best to make any trial of this substance. I hope they will take care to dig to a considerable depth to obtain it, although I should presume that two or three feet would be sufficient where the muck sand shows itself on the banks of streams; and yet the constant percolation of water from this stratum may carry off some of the fertilizing matters from I know not how great a horizontal distance.

In addition to the above circumstances, it ought to be borne in mind that this muck sand, on account of the minute division of its parts, is in the best possible state for enabling the roots of plants to act upon and absorb nutriment. Nor should it be forgotten, that in all cases when fresh dug, these sands give off the odor of sulphuretted hydrogen; which probably proceeds from the decomposition of sulphuret of iron, or some alkaline sulphuret, by the free sulphuric acid formed in the manner described by Dr. Dana, in giving a theory of the action of clays in agriculture. Very probably this sulphuret of iron may act an important part in fertilization by these muck sands;

and hence it is desirable not to use any, certainly in early experiments, which does not emit the odor above named.

These considerations, with the facts that have been detailed, excite a hope that this muck sand may prove an article of no small value as a manure. The specimen from Leominister, however, given in the preceding table, should be noticed as deficient in some points, which, according to the preceding views, are important. It has little if any soluble geine, and the salts are in small proportion. That specimen was received from Mr. Sewall Richardson, who says that it was taken seven feet below the surface, and that it has been dug three years, and exposed to atmospheric agencies. It may, therefore, have lost some of its fertilizing properties. Yet he says, "for the last four years I have applied it as manure on dry land, and find that it produces a good effect. One quart, applied to a hill of potatoes before hoeing, seems to prevent the effects of drought on the driest of our plains, and makes them yield potatoes equal to the best of our land." He says, also, that "it has as much effect on the skin, when first dug and dryed, by handling it, as lime, or ashes." It was in consequence of these statements that I subjected this specimen to analysis; although it bears but little resemblance to the muck sands in general.

The wide diffusion of this muck sand in the state, makes me more desirous of having it tested. I have already remarked that it may be found on the banks of all our streams, which have deposited alluvium. And I doubt not it may be found in most swamps; especially those that are underlaid by clay. From the banks of rivers it might be carted at a season of the year when the water is low, since the stratum usually lies but little above low water mark: and from other places excavated on purpose, it might be obtained at almost any season. Should only a small part of the fertilizing effect result from its use generally, which the facts detailed would lead us to expect, I should still feel amply repaid for my labor devoted to the subject.

Beneath the vegetable matter in most of our swamps, there is a fine sand, quite analagous in appearance to the muck sand that has been described; and from some facts that have come to my knowledge, I suspect that this possesses, in part, at least, the fertilizing

character of the muck sand. It probably contains some soluble geine and salts of lime, and sometimes gives off the odor of sulphuretted hydrogen; though perhaps this may result from decayed vegetables, as these sometimes emit an odor resembling that gas. I apprehend that this sand may be found often to possess enough of a fertilizing character to be profitably employed upon land.

Concluding Remarks upon Soils.

Though I have dwelt so long upon the analysis and improvement of our soils, it will be seen that I have touched only a few of its more important features, and that even these are but imperfectly considered. Many minor points, of no small importance, however, have been wholly passed over, or only alluded to; and sensible that I cannot do them justice at present, I shall not attempt to discuss them. My great object has been, after ascertaining the greatest deficiencies in our soils, to satisfy the Government that we have the means of remedying them and of making great improvements in them, by the aid of chemistry. If I may hope that I have accomplished this object, then I take the liberty to inquire, whether it be not important enough, and whether there is not enough still left to accomplish respecting it, to make the appointment of a *State Chemist* desirable? We ought to have still further experiments made on the subject of geine, and the salts, which the soils contain: also accurate analyses of the crops grown on soils with different manures; and investigations as to the manner in which calcareous matter acts upon vegetable and animal substances: as also experiments directed by an able and experienced chemist, on the best mode of bringing into use the vast deposites of geine and vegetable fibre which our state contains. And since we have chemists of this character among us, why should not the services of at least one of them be secured for this object? The geological surveyor might often collect substances for analysis; but if obliged to go as thoroughly into the chemistry of the subject as is necessary to valuable results, he cannot within any reasonable time accomplish the more appropriate objects of his appointment. In at least one state of the Union, where geological surveys are in progress, one gentleman is appoint-

ed, whose time and attention are exclusively devoted to the chemical examination of the soils, ores, &c., collected. And I would fondly believe, that Massachusetts will not rest satisfied, till this work is done at least as thoroughly as in any other state. I believe there is abundant labor for an experienced chemist upon our soils alone: but many other substances, found in the state, ought to be analysed, that their real value may be known.

I do not doubt but the Government and every intelligent reflecting citizen will feel the vast importance of energetic efforts to improve our soils so that they may sustain a larger population. This is the only way to check the tide of emigration that sets so strongly to the great West. For if our sons can be made to see the soil of New England doubling its increase, as I verily believe they might in one or two decades of years, the rich alluvia and prairies of the West will not be able to draw them away from the graves of their fathers; especially if they learn that those fertile regions will at length become exhausted of their geine and salts, and then will probably require as much labor to cultivate as the soils of Massachusetts.

Some, however, may contend, that it is more important, to transfer the New England character to the unsettled West, than to multiply our numbers and wealth at home. But the history of the world leads us to fear, that New England character cannot long be preserved except upon New England soil; or upon a soil that requires equal industry for its cultivation. Place New England men where the earth yields spontaneously, and the locks of their strength will soon be shorn. If we look over the map of the world, and the history of the past, we shall find as a general fact, that the brightest exhibitions of human character have been made, in regions where nature has done less, but art and industry more. If, therefore, we wish to increase the moral power of New England, it must be done by improving her soil, and increasing her resources and her population. If these views are correct, which I acknowledge do not fall in with the prevailing notions, they furnish a new stimulus for vigorous effort in the improvement of our soils.

12. Fossil Fuel.

Next in importance to the means of improving our soils, I have regarded the discovery of fossil fuel; that is, fuel dug out of the earth, and resulting from vegetables which have been buried there in former times; and, therefore, I have examined with no small care, every spot where such discovery seemed likely to be made. When I prepared my former Report, I confess my expectations were not sanguine that Massachusetts contained within her bosom any extensive deposites of coal; though aware that not a little peat might be found. But since that time, the enterprise and industry of some of our citizens have put quite a different aspect upon the subject, so far as coal is concerned; and I have made such extensive inquiries respecting peat, as leads me to suppose its quantity in the state has been much underrated. I will now proceed to give such details as will enable the Government to form an opinion on the subject.

Anthracite Coal.

In my former Report, I stated that, "we might reasonably look for anthracite coal in any part of the greywacke formations exhibited on the Geological Map." This extends in interrupted patches across the whole of the eastern part of the state, and at its southern extremity, embraces the coal beds of Cumberland, Rhode Island. I also marked on the Map beds of this anthracite in the east part of Cumberland, Rhode Island, and in Middleborough, West Bridgewater, and Wrentham, Massachusetts. In the autumn of 1835, since my Report was published, another bed was discovered in Mansfield, which led to the formation of "the Massachusetts Mining Company," "the Mansfield Mining Company," and "the Mansfield Coal Company," all of which have exhibited great and commendable perseverance to make explorations in spite of the general stagnation of business and enterprise; and their efforts have been crowned with far greater success than I could have anticipated. I shall describe the principal excavations that have been made by these

companies in that region, with the results to the beginning of last October.

The Massachusetts Mining Company commenced their explorations in 1835, on the farm of Mr. Alfred Harden, where a shaft sunk only 25 feet, struck a bed of coal 5 feet wide, and another only 1 foot thick, separated from the first by 10 inches of rock. The shaft has since been carried to the depth of 64 feet ; and from the bottom of it, in opposite directions and following the bed of coal, drifts have been extended 150 feet, and rail-ways laid for bringing the coal to the bottom of the pit, from whence it was, until recently, raised to the surface by a windlass and hand power ; but steam power is now used, which greatly increases the daily amount of coal raised. About 1,500 tons had already been raised from this mine, when I visited it in October ; and a drift had been carried from the bottom of the shaft, in a south-east direction, several feet across the rock strata, in search of new beds. Only one about a foot thick had been reached.

The explorations at this spot have been carried forward under the direction of Gen. Samuel Chandler, of Lexington, who seemed to me to have managed the whole concern with remarkably good judgment, and to have brought the principles of science to bear upon practice with singular success. In his printed Report to the Company, he says, that "although the region has been but very imperfectly explored, even where the strongest external evidences appear, yet four separate veins are known to occur on land leased to the Massachusetts Mining Company, situated at no great distance apart, and parallel in their line of bearing: two of which have been opened sufficiently to ascertain their thickness to be over five feet," &c.

The clerk of the company, William B. Dorr, Esq., makes the following statement in respect to these explorations, which must be regarded as very encouraging. "The Massachusetts Mining Company," says he, "at an expense of less than $15,000, with all the discouragements of a novel undertaking, the almost entire want of practical knowledge of the subject, and the cost of experiments which experience would have rendered unnecessary, have been able to raise from 1200 to 1500 tons of coal, worth from $5000 to $6000, at the lowest estimate both of the quantity mined and of its true

value." "The directors have unhesitating confidence in the eventual success of the mining operations at Mansfield; and nothing but the universal prostration of enterprise and business, has prevented their pursuing these operations on a scale commensurate with their confidence and the public importance of the subject."

There are two methods of ascertaining the value of this coal for fuel: both of which it is desirable to be applied. One is chemical analysis; by which we learn how much carbon, or combustible matter, it contains, and how much earthy residuum that is useless: and the other is experience in using it. In 1835 Dr. C. T. Jackson analysed two specimens taken from the depth of about 25 feet, and the results were as follows:

1st specimen.		*2d specimen.*	
Carbon,	98	Carbon,	96
Peroxide of iron and alumina,	2	Peroxide of iron and alumina,	4
	100		100

I have made but two trials with a specimen obtained at the mine last autumn, and the result is as follows:

1st specimen.		*2d specimen.*	
Carbon,	94	Water,	5.6
Residuum,	6	Carbon,	88.8
		Residuum,	5.6
	100		
Specific Gravity, 1.70.			100.

The amount of carbon in these specimens is a little greater than Prof. Vanuxem obtained from two specimens of anthracite from Rhode Island. In one he found an earthy residue of 5.07 per cent, and in the other of 15.60 per cent. He also found about the same per cent of water as I obtained in the second trial; this item having been neglected in the first trial, as well as by Dr. Jackson, as our chief object was to ascertain the amount of earthy residuum. The amount of carbon in the Mansfield coal is nearly equal to that in "the purest anthracite of Lehigh," in which Prof. Vanuxem found 3.3 per cent of earthy residue, and the mean of the four analyses given above is only 4.4 per cent of residuum. The composition, then, indi-

cates the very best kind of anthracite. Its specific gravity, however, is 1.70 ; while a specimen of Peach Mountain, in Pennsylvania, was only 1.49 ; and hence, perhaps, we might expect some more difficulty in producing perfect combustion in the former than in the latter.

As to the testimony which experience gives to the value of this coal, so far as that testimony is within my reach, it corresponds to what chemical analysis would indicate. It ought to be recollected, however, that beds of coal near the surface of the earth, are always more or less affected by the action of water, which insinuates itself into their crevices. I have understood, that from this cause the coals of Pennsylvania have improved since the beds were first opened. It ought also to be recollected, that coal from a new locality may be expected to require a little different mode of management to make it burn well ; and also that when men do not find such new article to conduct precisely like that which they have been accustomed to use, they are apt to infer at once that it must be of an inferior quality; and they are not willing to be at the trouble of making experiments to get over the difficulty.

"The quality of this coal," says Gen. Chandler, "has given very good satisfaction generally to the purchasers, notwithstanding it was taken by many under unfavorable circumstances."—"Many competent judges who have had opportunities of testing its qualities thoroughly, represent it equal, in their opinion, to the Pennsylvania Anthacite in all its essential properties."—"The fine coal has been taken in considerable quantities and used as fuel for steam power, and proves to be a very superior article for that purpose, &c."

Foster Bryant, Esq., of Mansfield, who appears to be very familiarly acquainted with all the mining operations in that region, states, that as the beds have been explored to greater depth the quality of the coal has improved, which he imputes to the action of the water upon the upper portion of the beds. This often prevents the thorough combustion of the coal, although it ignites without difficulty and burns well for four or five hours. He adds, that "the coal of Mansfield, even in its present impure state, is capable of being converted to all economical purposes, and contaminated as it now is by adventitious substances, it is a better, far better article, than the coals from

the Little Schuylkill were in 1831, and altogether better than the first year's produce from the Lackawana mines."

"The quality of the coal," says Mr. Dorr, "has afforded entire satisfaction to those who have taken the pains to give it a thorough trial, and to investigate its distinctive properties. Several of the directors use it exclusively for fuel, in open grates, cylinder stoves, and cooking ranges. It is found to ignite and burn best with a very moderate draught; and broken to about the size of a butternut. Uniformity in size is of course desirable. Under favorable circumstances, little difference is found in comparison with the best Pennsylvania anthracite, whether in relation to facility of ignition or intensity and durability of heat."

"The community generally, from feeling less interest in its success than the proprietors, will naturally take less pains in its use; and like every new discovery, its general introduction will doubtless be gradual."

The following testimony was given by the captain and passengers of the steamboat President, where the Mansfield coal was used, on a trip from Providence to New York:

New York, Dec. 25, 1836.

Dear Sir:—I received the sample of the Mansfield coal yesterday, which you sent to me for trial on board the President. I used it on the passage from Providence to New York, in the various kind of stoves we have on board, and was much pleased to find that it burnt very freely, making quite as hot a fire as any Anthracite coal hitherto used on board this boat. I consider it superior in quality to many kinds of Anthracite coal now in use in this city.

I am, very respectfully, your friend,

ELIHU J. BUNKER.

To Mr. Foster Bryant.

Steamboat President, Dec. 24, 1836.

The undersigned, passengers on board the President, from Providence to New York, with pleasure bear testimony to the excellent

quality of the Mansfield coal, with which the cabin fires were supplied during the trip. So far as they are able to judge, the article from Mansfield, used in the cabin, is fully equal to the Pennsylvania coal in all essential properties.

Richard Rankin, Frankfort; Thomas Lovett, Boston; John S. Barker, Lt. R. S., Newport; James S. Peters, Cortlandt, N. Y.; Benjamin Morse, New Fairfield, Conn.; George H. Riddell, Nantucket; Thomas B. Griffith, N. Y.; John Clark, Jr., Boston; Charles Howes, Boston; Thomas Ayling, Newtown; Daniel H. Johnson, Salem, Mass.; E. Nottebohen, Boston; John P. Davenport, do.; J. B. Hastings, do,; Joseph Pond, Philadelphia; Levi Pratt, Fitchburg; George H. Owman, Providence, R. I.; Henry B. Lloyd, Boston; John Whipple, Providence; Thomas Hopkinson, Lowell, Mass.; J. A. Etheridge, Dedham; G. M. Peck, Freeboro', Mass.; H. Sumner, Foreboro', Mass.; G. L. Brown, Providence; William Power, Bristol; Charles N. Cogswell, S. Berwick, Me.; George W. Lathrop, West Bridgewater, Mass.; Edward Ritler, N. Y.; B. G. Snow, do.; E. P. Robinson, do.; J. H. Tuck, Nantucket; Benjamin Morrill, Boscowen, N. H.; William S. Eastman, Baltimore; Thomas B. Parks, Berwick, Me.; Joseph Matthewson, Providence, R. I.

I have shown that the coal of Mansfield, and of Portsmouth, R. I., is embraced in the same general and continuous rock formation. Hence we have every reason to believe that the coal from every part of this great field will be essentially alike. Now the Portsmouth coal was formerly used to a considerable extent, and very fair experiments were made by Professor Silliman, (which I have detailed in my former report,) to ascertain the value of this coal for common fuel, as compared with that from Pennsylvania; and he comes to the conclusion that there is no important difference between them. There can hardly be a doubt, but the same conclusion may be safely applied to the Mansfield and Pennsylvania coal.

Exploration of the Mansfield Coal Company, and the Mansfield Mining Company.

The Mansfield Coal Company have simply sunk a shaft 64 feet near the centre of Mansfield, but have met with only a little coal: another shaft was sunk, half a mile north-west of the Harden farm, by the Mansfield Mining Company, to the depth of 84 feet, in which a bed only a few inches thick was crossed. A drift was then commenced at the bottom of this shaft, horizontally, towards the south-east so as to cross the strata. This had not been pushed far, when a bed of coal was struck, which, at the place, was about 10 feet thick; though on exploring it laterally for a few feet, it was found to be somewhat irregular; as indeed most of the beds are in the region, and as they are in fact in all coal fields. In crossing this vein, 25 tons of coal were thrown out, some of which is of a very superior quality; as may be seen in the collection (No. 207.) For specimens I am indebted to Mr. Joseph D. Clapp, the agent, who informs me that this vein has received the name of the "Wading Vein." When I visited it in October it had recently been discovered, and I have not since learned whether it has been pursued farther. I subjected 100 grains of it to analysis with the following result.

Carbon,	96
Alumina, Iron, &c.,	4
	100
Specific Gravity,	1.79

We have seen, from the testimony of Gen. Chandler, that four distinct beds of coal are already known upon land leased to the Massachusetts Mining Company. Mr. Foster Bryant states, that "seven distinct veins of coal have been struck in Mansfield, and the strongest indications are found of five more, one of which, from its great breadth is probably a continuation of the great vein at Cumberland." This is a great number to be discovered so early. For it ought to be stated that the whole of that region is covered by a coating of diluvial earth nearly 20 feet thick; so that it is only when in digging a well, or other excavation, that much chance exists for discovering

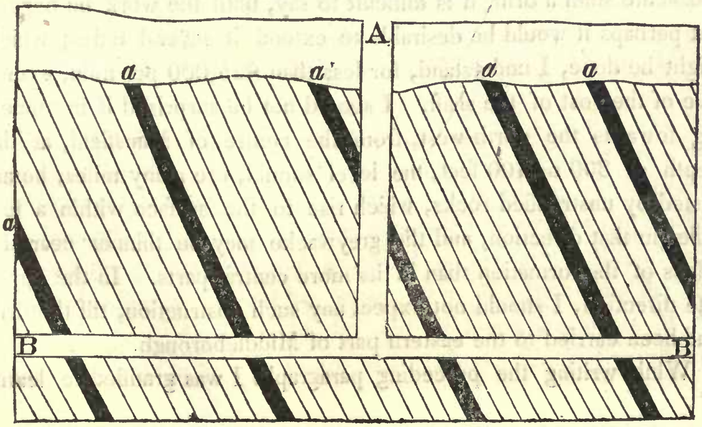
the coal: for I could not learn that any streams in the vicinity have cut through this diluvium. The fact that with such peculiar difficulties in the way, so large a number of beds have been discovered in the space of a little more than two years, is to my mind a very strong proof that the region of Mansfield is likely to prove a very rich and valuable coal field. By looking at the Geological Map of the State it will be seen that the greywacke formation embraces a large part of Bristol and part of Plymouth counties, as well as a part of Rhode Island. All this space which Mr. Bryant estimates at more than 400 square miles, is to be regarded as a coal field; and indeed, on the northern side, which is nearly 30 miles long, coal has been found in various places through the whole distance. A very large part of this extensive region is covered by a thick coat of diluvium, as in Mansfield; and where rocks appear in place above the surface, they are those varieties of the greywacke which are least likely to contain coal, being coarse and hard. The coal usually occurs in fine dark colored slate, alternating with gray sandstone: and these are very liable to be disintegrated and worn away. Hence, the best prospect of finding coal is where the rock is most worn away, and the soil deepest. Such is the rock every where found in Mansfield, and since an almost perfectly level plain exists there, over many square miles, I infer that the rock is very similar over its whole extent; and hence that probably we may hope for more success in explorations there, than in almost any other part of the coal region above described.

It is a fortunate circumstance that the great Rail-road from Boston to Providence passes across the centre of the plain of Mansfield, and within 80 rods of the Harden farm, where the most extensive exploration has been made. From this spot it is 15 miles to Providence, 11 to Taunton, and 26 to Boston. A more favorable situation could hardly have been chosen for the location of this coal, had the proprietors themselves selected the site.

Coal rarely if ever occurs in *veins*, properly so called: that is, occupying fissures *which run across the layers of the rock*. But it is uniformly found lying *between* the layers of the rock; that is, in what are called *beds*. If the layers of the rocks are horizontal, the beds will be horizontal. But generally, and especially in the graywacke

formation, the strata dip more or less beneath the horizon, and of course the coal beds will dip at the same angle. Being thus inclined, they will also run in the same direction as the upturned edges of the rock in which they are contained. Hence every coal bed will have a certain dip and direction. The extent to which the bed on the Harden farm in Mansfield has been opened, viz. 150 feet each way from the shaft, affords a good opportunity to determine these points in respect to that mine. I applied the clinometer and pocket compass at the bottom of this mine, and found the dip to be 53° north-westerly, and the direction nearly N. E. and S. W., though exhibiting minor deviations. And such are the dip and direction, within a few degrees, of all the rocks and coal beds that have been explored in the graywacke of Bristol county and in Rhode Island; except that on the Island it is said the dip is 90° south-easterly.

The preceding facts will enable us to judge respecting the situation of the coal beds in this great coal field; and perhaps show us what is the best method of research to ascertain how many beds actually exist, and also how they may be most advantageously worked. The following sketch may assist in understanding the subject. It is a supposed vertical section of the soil and rocks beneath the plain of Mansfield. It runs N. W. and S. E. so as to cross the strata of rocks at right angles. Twenty feet of diluvial soil are represented as covering the rocks, and they are shown dipping between 50° and 60° to the north-west. Several beds of coal, *a*, *a*, *a*, *a*, *a*, are shown lying between the strata.



Now it is evident, that if a trench could be cut through the loose soil across the edges of the strata, it would bring into view all the beds of coal that exist in them. But several gentlemen, who are practically acquainted with such operations, assure me, that such a trench would be far more expensive than it would be to sink a shaft several hundred feet into the rock, as shown above at A; and then to push horizontal drifts through the rocks at right angles to the strata, as is represented above by B, B, which crosses the coal beds *a*, *a*, *a*, *a*, *a*. And besides, were this done, and a rail-way laid at the bottom of the drift, as soon as a bed of coal was discovered, the mining and raising of it might immediately commence, without preventing the further prosecution of the drift.

This, then, appears to me, the thing that is wanted in the region under consideration. Suppose such a shaft, for instance, to be sunk 300 or 400 feet in the vicinity of the mine on the Harden farm, and a drift extended in opposite directions across the strata. We might be almost certain that these drifts would cross several valuable beds, since they are known already to exist in the vicinity. And thus the proprietors might have a fair prospect of remuneration, even if no new beds should be discovered: since this would probably, in the end, be the most economical way of opening the beds now known. But it is hardly to be conceived that no new and valuable beds would be discovered by extending the drift farther. Yet if they should not be found after carrying it forward a reasonable distance, it might be abandoned with little loss. How far it might be thought advisable to prosecute such a drift, it is difficult to say, until the work be begun: but perhaps it would be desirable to extend it several miles; which might be done, I understand, for less than $25,000 per mile, exclusive of the cost of the shaft. I should not be surprised if in tunneling towards the north-west, from the centre of Mansfield, at the depth of 300 or 400 feet, the level should, ere many miles, be arrested by unstratified rocks, which rise to the surface within a few miles in that direction, and the greywacke may be thinner near the edges of the formation than in its more central parts. In the opposite direction, I should not expect any such obstruction, till the drift had been carried to the eastern part of Middleborough.

While writing the preceding paragraphs I was gratified to learn,

that the three companies above named, as engaged in mining for coal in Mansfield, are about to unite their resources for examining the vicinity of that place, by a plan essentially the same as that mentioned above. At a season of such general stagnation of enterprise and business, this resolution is certainly deserving of high commendation. For should these companies succeed in laying open a sufficient number of beds of coal to supply the wants of the eastern half of Massachusetts, (and I am not without strong hopes that they may succeed,) so as to render our citizens independent of foreign importation, and reduce the price of fuel at least one half, hardly anything can be thought of that would give such a spur to industry and enterprise, and tend more to permanent prosperity. And allow me to inquire, whether the object is not of sufficient importance, and the prospect of success encouraging enough, to induce the Government of the State, by loan or otherwise, to encourage this undertaking. In general, it is probably best, to leave such enterprises to private efforts ; but in this case the investments must be so heavy that private companies may not feel justified in appropriating sufficient money to have the work done thoroughly : and if the Government, probably without any pecuniary loss, can lend its aid, it will give a powerful stimulus to private exertions. I make this suggestion, however, without any request on the part of these companies, and even with scarcely a personal acquaintance with any of their number.

Diluvial Drift of Coal.

General Chandler mentioned to me a mode of exploring for coal, which he had successfully adopted, and which may be of use to others, depending on a knowledge of the direction which was taken by the diluvial waters that deposited the deep accumulation of sand and gravel lying over the coal region. It is an ingenious practical application, and at the same time a beautiful illustration and confirmation of the general doctrine advanced in my former Report, that a powerful diluvial current has swept over this state from the north. Whenever in digging into the soil he found fragments of coal, guided by this principle, he dug in a northerly direction ; and never

failed to find the number and size of the fragments to increase until he arrived at the bed from which they were broken. Following the fragments in the opposite direction, they continued to decrease in size and number until at the distance of several rods from the bed they disappeared. Hence, if in digging through the soil no fragments of coal should occur, it might pretty safely be inferred that no bed of much size exists for several rods in a northerly direction; and if they are found, the explorer need be at no loss in what direction he will find the bed.

Coal Bed in Foxborough.

I ought perhaps to have described the coal bed in Foxborough earlier. For it is only about two miles from the excavations in Mansfield, and belongs to the same coal field. Good coal was obtained there, formerly, in two places a few rods apart: but the shafts are now filled up. A specimen of this coal gave the following results upon analysis:

Water,	5
Carbon,	77
Earths, oxides, &c.,	18
	100

Specific gravity, 1.86.

The quantity of earthy matter here is much larger than in the specimens from Mansfield; yet it is not much larger than some of the coals contain that are extensively used; and very probably the specimen which I analysed was comparatively poor. It is not probable, however, that this bed will be re-opened at present.

Coal Bed in Cumberland, Rhode Island.

The coal bed in Cumberland, Rhode Island, ought also to be noticed in this connection. For although several miles distant from Mansfield, yet it lies in the same rock formation, and only a mile or two beyond the limits of Massachusetts. This has been wrought

by the New England Coal Mining Company to the depth of 70 feet: but operations are now suspended in consequence of the destruction of the works by fire. At the out crop, beneath 20 feet of diluvium, its width was 9 feet; but at 40 feet in depth, it had increased to 14 feet. The dip and direction of the bed correspond essentially with those in Mansfield. For these facts I am indebted to Mr. Foster Bryant, who says also, that there was a decided increase in the value of the coal as it was taken from successively greater depths. I did not obtain any specimens for analysis from this mine; and I confess, that when I visited it, I was not so favorably impressed with appearances there as at the mines in Mansfield. I saw among the fragments thrown out, scarcely any impressions of vegetables, and much of the rock exhibited a glazed plumbaginous appearance, as well as a more crystalline arrangement of parts, than is usually found in connection with good coal. This I suppose to result from the greater nearness of this spot to the unstratified rocks, than the mines at Mansfield. These rocks have doubtless once been melted; and they have probably heated the coal beds so much in some places, as to obliterate the organic remains and convert the coal almost, and in some cases quite, into plumbago. Hence I should expect that the coal from such spots would be more difficult of combustion, and often contain more ashes. I noticed the same appearances to some extent at Foxborough, and still more strikingly at the coal bed in Wrentham, and both these places are quite in proximity with unstratified sienite or granite. Mr. Bryant, however, thinks the Cumberland coal as good as that in Mansfield; and both of them nearly equal to that from Pennsylvania. And I may be mistaken in these suggestions; but I thought it might be well to mention the insalutary influence of unstratified rocks upon coal, that explorers might be put upon their guard.

Several other excavations in search of coal have been made in Mansfield and its vicinity; but as they are not large, and little success has attended the efforts, I do not think it necessary to go into details respecting them; although I visited all of which I could obtain any knowledge.

The beautiful impressions of vegetables found upon the slate that embraces the coal at Mansfield, are deeply interesting in a scientific

point of view, and will receive due attention in the proper place. But I do not think proper to attempt a description of them at this time.

The Worcester Coal.

No attempt has been made since my former Report to resume operations at the Worcester coal bed, although such I believe has been the intention of the proprietor. This coal being in a decidedly older class of rocks than those at Mansfield, is of course more mineralized, and will burn with more difficulty. Yet it is certain, that it is used to advantage in some manufacturing establishments, if not in private families, and hence it may be of great importance. I have nothing new to add respecting it, however, except an analysis of an ordinary specimen, probably not the best, that happened to be in my possession.

Water, ...	3
Carbon, ...	75
Earths and oxides, ...	20
	100

Specific gravity, 2.12

By looking at the Geological Map of the State, it will be seen that the rock formation which embraces the Worcester coal, extends to the mouth of Merrimack river ; and of course, coal may be found in other parts of the formation besides Worcester. In Bradford, where the general aspect of the country, the character of the soil and of the rocks, correspond almost exactly to the region around Worcester, an exploration is going on for coal by means of boring, which has been continued to the depth of nearly one hundred feet. I saw, however, no peculiar encouragement at this place, more than at almost any other in the town. Should coal be found there, it will undoubtedly be of the same character as that in Worcester.

Bituminous Coal, West Springfield.

In my former Report (p. 232, 2d edition) a locality of bituminous

coal is described on the north bank of Agawam river in West Springfield, where there is a remarkable upward bend in the sandstone rocks; the arch having a span, however, of only a few rods. Within two years past, the banks and bed of the river at this place have been somewhat extensively excavated for building factories. The consequence was, the bringing to light of coal in larger quantity, and of the most beautiful variety, that I have ever seen. (No. 206.) It appears to exist here in the form of small and irregular veins, the coal also being filled with numerous thin veins and crystallizations of calcareous spar. This is a most remarkable mode of occurrence, and very interesting in a scientific point of view: and perhaps, also, of consequence in a practical point of view: otherwise I should not here describe it. Coal is, indeed, described in geological books as sometimes occupying fissures in rocks, along with fragments of those rocks: but in this case the coal is broken by mechanical violence. Yet at West Springfield, it has evidently been filled into the fissures, just as the associated calcareous spar was, by a chemical agency. The latter may have been deposited from water: but I can conceive of no way in which the coal could have been formed, but by sublimation and subsequent solidification, as the temperature was reduced. In short, my supposition is, that coal may exist beneath this spot, and that by the agency of trap rocks, a part of it was melted, the superincumbent sandstone forced up, and into its fractures the melted and sublimated coal ascending, but not being able to escape, was reconsolidated into coal. I am not aware of any analogous fact having been noticed elsewhere; and this makes me less confident in this hypothesis. Yet every fact respecting this coal corresponds to it, as does also its chemical composition. For if it were the result of sublimation, we might expect it to be free from those earthy and metallic matters, that I believe have always been found in coal upon analysis. And such, it will be seen, is the fact with the West Springfield coal: or rather it is free from impurity as most crystals are. It is, indeed, difficult to separate mechanically from this coal all the thin layers of calcareous spar with which it abounds, and hence there will often be a small residuum after burning in a platinum bowl: but diluted cold nitric acid dissolved this almost entirely, with effervescence in three trials which I made; and hence I conclude it to be

carbonate of lime, which ought not to be reckoned as an impurity, because existing only in the fissures of the coal.

A pure specimen of this coal yielded, upon analysis, as follows:

Volatile matter, (water and bitumen,) -	22.00
Carbon, - - - -	77.97
Earthy residuum, - - -	0.03
	100.

The method which I adopted to ascertain the amount of volatile matter, was simply to heat the triturated coal in a broad platinum bowl, nearly to redness, until all the bituminous odor had disappeared. This, I am aware, is not a very satisfactory mode of determining the amount of bitumen; but it is sufficient for my present purpose to show, that a rather large proportion of bitumen exists in this coal. And every one must see, that its composition is such as would make it one of the finest coals ever discovered, could it be found in sufficient quantity.

If the hypothesis above advanced be true, there would result as an inference a probability, that, by boring into the sandstone in the bed of the river at the highest part of the arch, a bed of coal might be discovered. And since the span of that arch is so limited, it seems hardly possible, that the upheaving power can be situated more than 100 or 200 feet below the river: that is, the trap rock, the supposed disturbing cause, would probably be struck before that depth were reached; and since the coal, if it exist, must lie above the trap rock, this also would be reached. Whether the probability of finding a bed of workable coal is strong enough to justify the expenditure of a few hundred dollars in such an exploration, others concerned can now judge as well as myself.

The spot where this coal occurs, it may be well to mention, lies directly on the route of the rail-road from Springfield to Albany.

Peat.

Taking the state as a whole, peat is but little used, either as fuel or manure; though most employed for the latter purpose. Yet for both purposes its use is rapidly increasing, especially in the eastern part of the state, where fuel is more expensive. In view of its im-

portance, I have made some efforts to ascertain its probable amount in our swamps. But this is very difficult; both because our swamps, where it occurs, have been but slightly explored, and because much is called merely mud, that deserves the name of peat. Several gentlemen, however, to whom I addressed inquiries on this subject, in different towns, have ventured to give an opinion as to the thickness of the beds, and the number of acres of peat found there. The following statement embraces nearly 50 towns; though by no means all in which I know peat to exist. But my object at this time is to give data for forming an approximate estimate of the amount of this deposite in the state. Several other localities will be found in my ormer Report.

TOWNS.	Thickness of the Beds.	Acres covered by Peat Swamps.	Use.	Authority.
Andover,	1 to 8 feet.	More than 2000.	Fuel and manure.	Alonzo Gray.
Athol,	2 to 3 feet.	Swamp 2 miles long, 80 rods wide, (300)	Scarcely used.	Alden Spooner.
Abington,	Abundant.			Thom. H. Perry.
Amesbury,	10 feet, sometimes.	100 acres at least.	Little used.	Patten Sargent.
Barnstable,	15 feet, sometimes.	200 acres.	For fuel only.	
Buckland,	1 swamp 30 ft. deep of mud.	50 acres swamp.		Silas Smith.
Bellingham,	3 to 8 feet.	"Probably 5 or 6 acres."		John Cook, 2d.
Bernardston,		30 to 40 acres, much peat.	Manure only.	H. W. Cushman.
Bridgewater,	Extensive beds.		Fuel and manure.	P. Leach.
Concord,	2 to 8 feet.	500 to 700 acres.	do do	Cyrus Stow.
Carver,	8 to 10 ft. of mud in swamps.	500 to 800 acres bog swamps.	Not used.	John Savery.
Chilmark,	Various.	Perhaps 100 acres.		
Dennis,	1 to 4 feet.	100 to 200 acres.	Fuel.	L. Nickerson.
Dighton,	Plenty.		Not much used.	
Duxbury,	2 to 20 feet and more.	Abundant.	Fuel and manure.	Gershom Bradford.
Eastham,	2 feet to unknown depth.	do		George Collins.
Falmouth,	10 to 15 feet.	20 to 30 acres.	Manure.	Wm. Parker.
Groton,	5 to 20 feet.	Hundreds of acres.	Manure chiefly.	J. Green.
Hingham,	2 to 6 feet.	50 to 100 acres.		Henry Cushing.
Halifax,	2 to 10 feet.	100 to 200 acres.	Beginning to be used	J. P. Thompson.
Hanson,	1 to 10 feet.	1000 acres.	Fuel and manure.	F. P. Howland.
Hanover,	Rather abundant.		Lately used.	A. G. Duncan.
Holden,	Not abundant.		Manure only.	John Chaffin.
Kingston,	2 to 10 feet.	Many swamps.	Manure.	Asaph Holmes.
Lunenburg,	Inexhaustible.	100 acres.	Not used.	
Longmeadow,		Perhaps 10 acres.		
Ludlow,	12 to 15 feet.	50 acres.	Manure.	H. W. B. Alden.
Lynnfield,	10 to 12 feet, sometimes.	100 to 200 acres.		William Perkins.
Methuen,	3 to 6 feet.	More than 50 acres.	Fuel.	Stephen Parker.

TOWNS.	Thickness of the Beds.	Acres covered by Peat Swamps.	Use.	Authority.
Millbury,	3 to 10 feet.	Extensive beds.	Fuel.	Asa H. Waters.
Natick,	3 to 6 feet.	500 acres tested, 300 to 400 more.	do	Chester Adams.
Oxford,	4 to 12 feet.	Several hundreds.	. . . .	Stephen Davis.
Nantucket,	1 to 14 feet.	985 acres.	. . . .	Jared Coffin.
Randolph,	1 foot to a great depth.	. . . .	Fuel chiefly.	Zenas French, Jr.
Rowley,	3 to 6 feet.	More than 500 acres.		
Roxbury,	30 inches average.	. . . .	Manure chiefly.	A. A. Hayes.
Spencer,	2 to 30 feet.	1000 to 2000 acres.	Fuel this year.	Jonas Guilford.
Southborough,	Thick.	500 acres.	Fuel and manure.	Joel Burnet.
South Reading,	3 feet average.	200 acres.	. . . .	Lilley Eaton.
Weston,	10 feet and less.	Numerous swamps.	Manure.	A. Bigelow, Jr.
Wales & Holl'd,	4 to 10 feet.	200 acres.	do	E. G. Fuller.
Wilmington,	"Two cuttings deep."	"Some hundreds."	Fuel.	Silas Brown.
Westford,	Abundant.	. . . .	. . . .	Julian Abbot.

It will be seen, that scarcely any towns, in the four western counties of the state, are mentioned above. This is partly explained by the fact, that fuel is more plenty there than in the eastern counties, so that public attention has never been directed so much to our fossil resources. But I think it undeniable, that the amount of good peat in the western counties is much less than in the eastern. Although perhaps the swamps abound as much in vegetable matter, that would be useful in agriculture, yet it does not seem to be converted into genuine peat, though I doubt not that it will be easy to find a large amount of it when there is a demand for it. Excluding these western counties, and taking the amount of peat given in the above statement as a fair average of its quantity in all the towns of the other counties, (excluding the large towns,) it would follow, that 80,000 acres, or 125 square miles, are covered with peat in that portion of the state, being an average thickness of 6 feet 4 inches. This area and depth would yield not far from 121 millions of cords. If this should be thought by any to exceed the quantity of good peat existing in that section, I presume no one will consider it too high an estimate of the amount of swamps filled with vegetable matter. I presume it falls far short of the true amount. And we hence get an enlarged view of the quantity of matter in the state that may be employed as fuel, or in agriculture, that has hitherto, except in some limited districts, remained almost untouched. It is true, that peat is not so convenient and agreeable a kind of fuel as good wood or coal; yet it certainly answers a very good purpose, and the facts in the case tend to allay the apprehension, which must sometimes rise in the mind of one who sees, in the gradual diminution of our forests, a future check to our prosperity and population. It is gratifying to learn, from so many towns, that the inhabitants are awaking so much to the use of peat and peaty matter. Some gentlemen have even spoken of it as a "peat fever." I hope it has not yet reached its crisis.

13. Metallic Ores.

To this department of our mineral resources I have found time, during the year, to give but a very inadequate attention. Some new

localities, however, have come to my knowledge, and the results of all that I know of them will now be given.

Carbonate of Iron in Newbury.

As one passes from Newburyport to Kent's Island in Newbury, just as he arrives at the northern margin of the salt marsh surrounding the island, he will notice abundant fragments of a white rock, coated over with iron rust. Suspecting it to be carbonate of iron, I collected specimens (No. 176) and have subjected one to analysis with the following results:

Carbonate of lime, - - - -	45.67
Carbonate of magnesia, - - - -	8.97
Proto-carbonate of iron, - - -	21.76
Proto-carbonate of manganese, - -	16.10
Silica and alumina, - - - -	3.34
Loss, - - - - - - -	4.16
	100.

Specific gravity, 2.94.

The small quantity of iron in the specimen above analysed, and the abundance of lime and magnesia, leaves one in doubt whether it ought not to be regarded rather as a magnesian limestone, containing a large amount of iron and manganese. A more important question is, whether, with so little iron, this mineral can be profitably wrought. And yet some of the ores of spathic iron in Europe that are smelted, contain only a little more than 20 per cent of the carbonate of iron. This ore is regarded in Europe as one of the most valuable of all the ores of iron, especially for the manufacture of steel; the well known German steel being obtained from it: and the character of most of the substances mixed with it in Newbury, especially of the lime, will probably render any other flux unnecessary in working it, unless it be clay. At any rate, as I noticed the quantity of the mineral to be very great at the spot above named, and as I may not have selected the richest specimens to be found there, I have thought it would be best to call the attention of the Government to the locality.

Magnetic Iron in Warwick.

It was not till too late in the autumn to visit the spot, that my attention was called to a locality of magnetic iron in Warwick, which, from the description given me, is probably the most extensive in the State. Yet I am told that an attempt to work it some years ago was abandoned, on account of some supposed impurity. I felt, therefore, desirous to determine its composition, and having obtained a specimen (No. 177) through the kindness of Alden Spooner, Esq., I made a single analysis with the following results:

Protoxide and peroxide of iron, - -	66.4
Oxide of manganese, - - - -	16.6
Silica and alumina, - - - -	17.0
	100.

Specific gravity, 4.47.

The large quantity of manganese in this ore and its great compactness of structure, are probably the cause of the difficulties that were met in attempting to work it. Probably they might be overcome by the use of anthracite coal in a blast furnace, or still more effectually, by the use of the hot air blast, which is coming extensively into use in our country: since probably all that is wanted is an increase of heat. Some other substance besides manganese, whose presence is injurious, may have escaped my notice in the analysis, especially as I have not found time to confirm it by repetition. But an extensive bed of good iron ore ought not to be abandoned without very thorough trial: and if what I have here given shall call the attention of gentlemen, who are interested in the reduction of iron ore, to this deposite, my object will be accomplished.

Chromite of Iron.

In the second edition of my former Report, (p. 366,) I called the attention of the Government to several deposites of this uncommon and valuable ore, especially to one brought to light in Chester by Dr. H. Holland. That gentleman has recently furnished me with

additional information respecting the extent and composition of this ore, which I will state in his own language.

"The chrome ore," he says, "appears only in the eastern portion of the serpentine. I have found three distinct 'out-cropping' veins of the ore, or more properly *couches*, crossing the serpentine which is schistose and deep green, east and west, from 5 to 18 inches in width. I had a man blast one of the couches, and with a few hours' labor procured some 1200 pounds of the ore. I have one mass very pure of 60 pounds."

"I have tested the mineral as accurately as possible to determine its comparative value, and found it upon analysis, similar to Uralian chromite of iron, giving from 52 to 53 per cent of oxide of chrome, as it enters into composition, a protoxide. The iron is from 33 to 35 per cent, a peroxide, by calcination: which removed by hydrochloric acid, from the residuum of first calcination, *gave a distinct trace of platinum, as I considered it.*"

"Perhaps I might have been mistaken. I was led to notice it, from the fact that platinum is found associated with chromite of iron in Siberia as well as in the chromite of iron and iron sand of St. Domingo. The Chester chromite of iron has been tested by the Messrs. Tieman of New York, practical chemists. When made fine and freed from the matrix, silex, alumina and magnesia, as pure as usual for the arts in gross, it is found to yield, like the Maryland and Pennsylvania chrome ore, about 43 per cent of protoxide of chrome, which combines with the potash."

It is well known that some of the most beautiful paints in use, as the chrome yellow, chrome green, &c. are prepared from this ore. And to such a use it is Dr. Holland's intention to apply the Chester chromite, whenever it can be done profitably. The foreign salts of chrome have till recently been sold at so low a rate, that it has been impossible to compete with them in a country where labor is so dear as among us. But these articles have recently risen in market: and it seems hardly possible to doubt, but that a mine of chromite of iron must ere many years become exceedingly valuable. A few years since, Dr. Holland prepared several salts from the Chester chromite, and he has been kind enough to send me the only parcels of them yet remaining, and I have put them into the collection forwarded here-

with. No. 220 is a specimen of the Chester chromate of iron: No. 221 chromate of potassa: No. 222 chromate of lead, or chrome yellow: No. 223 dichromate of lead.

Hematite Iron Ore. (Limonite.)

I formerly supposed that the rich beds of this ore in Berkshire were contained in a tertiary formation; but an examination of many other beds in New York, has satisfied me, that the beds, which at their upper part are mixed with clay and soil, extend downwards, into the older rocks, the mica slate and talcose slate of Berkshire county. Indeed, at West Stockbridge, (the only bed in Berkshire that I have recently examined,) the excavation has proceeded so far as to bring to view the ore that has never been disturbed, having the same inclination as the rocks of that region; while we see that all the upper portion has been broken up and mixed together by diluvial and alluvial action. This appears to me to be an interesting and important fact. For had this ore extended no deeper than the loose soil, it would ere long have been exhausted. But if it forms beds in the rocks beneath, there is little danger that the bottom of it will ever be reached.

I am informed by E. B. Garfield, Esq., that several hundred tons of the Limonite have been dug in the south part of Tyringham, and that "strong indications of extensive beds" exist there. And I have already alluded to the probable existence of an extensive bed in the west part of New Marlborough. I mention these facts, because no notice was taken of them in my former reports, and because they add another item to the rich list of mineral resources in Berkshire county.

Copperas (Sulphate of Iron) from the Sulphuret of Iron.

I am informed by Ethan A. Greenwood, Esq., that at the copperas works in Hubbardston, not less than 75 tons of that salt, of good quality, are annually manufactured, and that the quantity of ore is inexhaustible; a fact of which any one I think will be convinced,

who will visit the locality. I see not why these works may not be carried on profitably to a very great extent.

Galena in Uxbridge.

A vein, or more probably a bed, of the sulphuret of lead, exists on the farm of Chilon Tucker in the south-west part of Uxbridge. It is in quartz rock and has been excavated a few feet. But the indications are certainly not very encouraging. Facts of this description, however, should be recorded, as they often lead to valuable discoveries.

Blende, Galena and Copper Ore in Russell.

John Gould, Esq., has sent me from his farm in Russell, specimens of quartz containing sulphuret of zinc, sulphuret of lead, and a small quantity of sulphuret of copper. The ore with its gangue exactly resembles that at the Southampton mines, and I doubt not but there exists in Russell another vein similar to those in Southampton, Hatfield, Williamsburgh, &c., which I have formerly described. I have learned nothing of the extent of the supposed vein in Russell.

Galena, Blende, and Titanium, in Norwich.

A similar vein of ore has been discovered in Norwich, and has been wrought to some extent by the proprietor, Mr. Quartus Angell, who has sent me specimens, and says, that the vein is about three feet wide. The ore, which I consider as titanium without chemical analysis, appears in these specimens to be more abundant than the others. A variety of porcelain clay occurs at the same place, which I shall notice farther on.

Galena in West Stockbridge and Alford.

Charles B. Boynton, Esq., of West Stockbridge, informs me, that galena occurs in the south part of that town; and I am told also by Roswell Picket, Esq., that the same ore is found a mile north of

the centre of Alford. It is possible that the two localities, being so near each other, may have been confounded ; but more probable that the same vein extends into the two towns. I know nothing of the appearance of the ore in the rocks.

With the exception of that in Uxbridge, I have not been able to visit any of the above mentioned localities of lead, zinc, and copper ore, chiefly because they were in most instances not made known to me till too late in the season. Their existence, however, should be recorded, and the requisite examinations can be made at a future time.*

14. Ochres and Stone Paints.

It is well known, that the oxide of iron, mixed with clay or soil, forms the paints called ochres. Although very many places in our soils have an ochrey appearance, yet I have not till recently met with any deposites in Massachusetts that appeared to me to promise much for paints. Those of which specimens will now be found in the collection herewith sent, seem to me worthy the attention of those who prepare colors.

The deposite which promises far more than any other that I have seen, accidentally arrested my attention, as I was passing the farm of Josiah Sheldon in the west part of New Marlborough. In several places over a hill embracing a number of acres, he has made excavations a few feet deep, and found an abundance of yellow and light red ochres, (see Nos. 164, 165) which probably might yield some of the best of this sort of paints. And besides, it seems very probable, that

* Mr. Thomas H. Perry, of Abington, informs me, that not long since several ounces of quicksilver were washed out from a bushel or two of sand on the margin of a pond on land of Benjamin Hobart, Esq. That gentleman has shown me a specimen, and says, that the sand in which it was found had been previously carted from an excavation of considerable depth in the vicinity. He says that the spot is quite an unfrequented one, and that he can conceive no way in which the quicksilver could have been accidentally spilled there. He has not, however, examined the excavation to ascertain whether more may not be found. It would be premature therefore, to decide that this is actually a locality of native quicksilver; but the fact would be so interesting should it prove to be so, that I give this note in order to excite to further examination. Near the same spot, Mr. Hobart informs me an excavation a few feet deep has been made in search of coal in the graywacke, and some impure specimens obtained, and preparations are making for further explorations.

there will be found in this field a rich bed of the hydrate of iron, or the hematitic iron ore, so abundant in other parts of Berkshire county.

No. 163 was obtained from what is called the Jewett farm, in the north part of Rowley, on the road to Newbury. It occurs in a low spot of ground, and has been formerly used for painting a house. The specimen is of a coarser texture than those from New Marlborough: but the former excavation was nearly filled up, and I had no time to have it re-opened; so that, perhaps, this specimen does not exhibit a fair sample of this locality.

No. 161 was sent me from Athol, by Alden Spooner, Esq., who says that it occurs in the north part of the town, and also in Templeton; but he gives no farther particulars.

No. 162 is from Monroe, for which I am indebted to Martin Ballou, Esq. He informs me, that it was formerly dug to some extent and prepared for paint; but not being in much demand, the work was abandoned. It certainly appears as if it might be valuable.

While this report was in press, I received from Bedford a specimen of yellow ochre of very good quality; but too late to be added at present to the state collection. I am informed that it occurs there "in two or more places," and in considerable quantity.

In my former Report, I suggested the use of the sulphate of baryta, which occurs in great quantity in Hatfield, as a paint—a patent having been taken out for its preparation. But I am not aware that the Hatfield stone has been employed for this purpose. Other rocks, also, which have of late been used as lithic paints, abound in this state. Soapstone, of which we have such inexhaustible quantities, is considered best for this purpose, and serpentine is also employed. These are ground with whale oil; and in Connecticut, where they have been manufactured, they are sold for five dollars per hundred pounds. They answer a good purpose as a basis for common paints, especially for the roofs of houses. I should presume that the newly discovered serpentine in Lynnfield is very well adapted for this object, being unusually soft and free from foreign minerals.

15. Moulding Sand.

I have been surprised to find, on inquiry of gentlemen in various

parts of the state, who are engaged in casting iron and brass, that nearly all their moulding sand is brought from beyond the limits of the state; and most of it from as great a distance at least, as Hudson river. I feel a strong confidence that this need not be always thus; and that careful research may bring to light good moulding sand within our own limits. Captain Lemuel Drake, of Easton, who has the management of extensive castings in iron, informs me, that he has obtained moulding sand, though not of the best quality, in Bridgewater, Medfield, Easton, and Foxborough. No. 166 is a specimen from the last named place, and No. 167 is from Montague; which I have placed in the Collection because it bears a resemblance to good moulding sand, although it has not been thoroughly tried. For a similar reason I have put up No. 168, from Norwich. It appears to be the result of the decomposition of granite, and may perhaps answer in the casting of brass. I have one or two other specimens, which I mean as soon as possible to submit to the examination and trial of men practically acquainted with the subject.

A. A. Hayes, Esq., of Roxbury, informs me, that a variety of quicksand is sometimes employed there by the brass founders, and that it makes a sharp impression. The same substance is used in Carver, as I am told, by John Savery, Esq., for parting the moulds of castings, and for the case of tea-kettle spouts.

My statements on this subject are so immature and meagre, that I should not give them, did I not hope thereby to excite observing men to notice substances that might be employed for moulding sand, which may fall in their way.

16. Porcelain and Pipe Clay.

Kowing how important in several manufactures is white clay which contains no iron, and how rare it is in New England, I have sought after it with care. It has long been known that such a clay exists at Gay Head, and in other places on Martha's Vineyard; and it has been used for several purposes: yet it is not delicate enough for the manufacturer of porcelain, though valuable for coarser articles. During the past winter, specimens have been sent me from the vicinity of the lead and zinc ore in Norwich, noticed above, which

appear to be a variety of porcelain clay ; and so far as I can judge from the imperfect description that has been furnished me, it appears to be abundant. Some of this, along with a specimen from Gay Head, I have subjected to analysis in the usual way, and obtained the following results :

	Gay Head Clay.	*Norwich Clay.*
Water of Absorption,	9.00	8.00
Silica,	62.26	53.40
Alumina,	29.31	36.26
Lime,	0.18	0.24
Magnesia,	0.45	0.68
Manganese,	0.15	0.20
Loss,	-	1.22
	101.35	100.

No iron could be detected in the above specimens ; (Nos. 144 and 145 of the Collection.) And since clay of this description is so important for the manufacture of fine bricks, white pottery, and porcelain, it will be an object to have farther examinations made of the Norwich bed. Its composition corresponds very well with that of many of the European porcelain clays, although I believe in them no manganese has been detected. But the minute quantity found by me cannot affect the value of the clay. Some of this clay is quite hard.

It is by no means all of our white clays that are destitute of iron, as may be seen by examing Nos. 142 and 143. And it may be well to mention an easy method of determining, when chemical tests are not at hand, whether a clay contain iron or not. If it does not it will not turn yellow or red when burnt strongly in the fire. The red color of our common bricks is occasioned by the iron which they contain, and which is peroxidised by the heat.

17. Clay as a substitute for Fuller's Earth.

In my former Report I mentioned the fact, that the common clay

of the Connecticut valley had been used as a substitute for Fuller's Earth. But I was not till recently aware how extensively this substitution had been made. I am told by the Agent of the Woollen Factory in Northampton, that this substitution is made very extensively in this state and in Connecticut, and that the clay is considered even better than the Fuller's Earth for cleansing the dye-stuff from cloth. That in Northampton has been considered as rather better than in other places; and hence it is transported often quite a distance. It is also used in private families for extracting grease and oil from cloth. It is first made into a paste, and then applied and suffered to dry. It doubtless operates by its great absorbing power. When applied to the tongue it adheres very firmly. No. 183 is a specimen from Northampton.

I learn that the clay in the north part of Worcester County is employed in the same manner; and I doubt not but the variety proper for this use may be found in many parts of the state; although that in the valley of the Connecticut appears to be rather better than any that I have met with elsewhere. Fullers' earth, which is brought from England, sells, I am told, for $10 per ton. The clay can cost nothing but the transportation.

18. Feldspar and Albite for the glazing of Porcelain Ware.

The articles of pottery and porcelain made from white clay need to be covered with a glaze of some other substance: that is, with an enamel, or glass: for the clay in its pure state does not melt in common furnaces. Now feldspar and albite, whose composition is very much alike, except that the latter contains soda and the former potassa, on account of the alkalies in their composition, may be melted in a strong heat: and hence they are employed for the most delicate kinds of glazing. Common glazing, which consists of powdered gun flints, litharge and table salt, is so soft as soon to yield to the mechanical and chemical agents to which the articles are exposed; and it would be very desirable that feldspar might be employed in all cases, though, as the process for its preparation is at present conducted, it would be more expensive.

I know of no attempt to employ any of the feldspar of Massachusetts for glazing; and yet we possess in our granites, sienites, and gneiss, inexhaustible quantities, and much, no doubt, pure enough for this purpose. Can there be any doubt, for instance, but that the adularia of Brimfield, Southbridge, &c. would furnish a most admirable article, since it is nothing but the very purest variety of feldspar. The best locality of albite in the state is in the north-west part of Chesterfield, on the farm of Mr. Clark: and I have understood that it has been purchased not long since, by a company in New York, for the purpose of using it in the manufacture of China ware, or porcelain: but I have not learned whether they are now prosecuting the work.

Beds of feldspar and albite have been quarried in Connecticut, within a few years past, with much success. In Middletown alone, in the year 1836, seven hundred tons were dug out; six hundred of which were shipped to Liverpool.*

19. Feldspar and Mica for obtaining Potassa.

Good feldspar contains nearly 20 per cent, and mica 16 per cent, of potassa; and it has recently been proposed in Europe to extract the alkali by calcination with lime. While our forests remain so extensive as at present, we shall not need to resort to this method to obtain potassa. But should coal ever become the principal fuel, it is gratifying to know that we have so abundant a source of this valuable substance. Albite, treated in like manner, would yield soda, though only about 9 or 10 per cent.

20. Materials for Water-Proof Cement.

I have already expressed the opinion that the best materials in the state for making a mortar that will harden under water, and which goes by the name of Water Cement, Hydraulic Cement, Roman Cement, &c., had not yet been used. I presumed that the argillo-ferruginous limestone, of Springfield and West Springfield, (No. 185,)

* Prof. Shephard's Geological Report, p. 72.

much of which occurs in nodules, which are now thrown away, is much better adapted to this purpose than the fetid limestone in use. I am confirmed in this opinion by the following remarks, which I have translated from a recent work by Professor Mitscherlich, of Berlin, than whom no better authority could be quoted. He says, "the best hydraulic lime is obtained from an argillo-calcareous rock, which is found in concretionary masses in marl; (the West Springfield rock, would in Europe, probably, be called *red marle.*) If this be reduced into a thick paste by water, it becomes solid as rapidly as gypsum: its solidity increases with the time during which it is immersed, (in water,) and it finally acquires the hardness of limestone."* I felt some little doubt what might be the effect of the magnesia which analysis shows this rock to contain. But Mitscherlich says, that "according to experiments in the small way, magnesian limestone merits the preference over the carbonate of lime." So that I very much hope that some of our enterprising citizens will make a trial of this limestone—tons of which can easily be obtained where excavations are going on in the Springfields.

Another substance mentioned by this writer as valuable for water-proof mortar, deserves to be noticed, especially as it may be of service to the inhabitants of Berkshire, where the common hydraulic limestone does not occur. "A marl," says Mitscherlich, "which contains from 13 to 19 per cent of clay, makes a good hydraulic mortar; and if the clay contains an excess of silica, this circumstance increases the good qualities of the mortar." He refers, I presume, to indurated marl: but I know of no reason why that which is pulverulent may not answer equally well, after being burnt into quicklime.

Another mode of preparing the water-proof mortar, is by mixing certain substances with lime in particular proportions. *Puzzolana*, which is a substance ejected in former times from volcanoes—a kind of volcanic ashes—is one of the ingredients that has been employed from the earliest times. *Trass* or *Tarras*, is a vesicular decomposing basalt, which has been extensively employed for the same purpose in Holland, in the construction of dykes against the sea. I am satisfied that the vesicular decomposing amygdaloid, so common

* Elémens de Chimie, par E. Mitscherlich, Professor de Chimie a Berlin, &c.; tome Troisieme, p. 120. Bruxelles, 1836.

in the region of Connecticut river, is so very similar to tarras and puzzolana, that it might profitably be employed for the same purpose. I have accordingly subjected a specimen to analysis, (No. 160,) taken from Mount Holyoke, in the north-east part of Belchertown, where great quantities of it may be obtained. The following are the results.

Water, - - - - - -	8.50
Silica, - - - - - - - -	53.70
Alumina, - - - - - - - -	13.00
Peroxide of Iron, - - - - -	21.00
Oxide of manganese, - - - - -	0.19
Lime, - - - - - - -	0.70
Magnesia, - - - - - -	0.15
Sulpher, and loss, - - - - -	2.76
	100.

By an analysis of Bergmann, puzzolana has the following compotion :

Silica, - - - - - -	55 to 60 per cent.
Alumina, - - - - - - - -	19 " 20 "
Calcareous matter, - - - -	5 " 6 "
Iron, - - - - - - - -	15 " 20 "

The correspondence between this analysis and the one which I have given, is near enough to show that in all probability both would answer almost equally well for the water cement. And I strongly hope that this substance, for which there is such an increasing demand, will not much longer be imported from Europe.

21. Steatite or Soapstone.

Waving all remarks respecting the strictly scientific meaning of the terms steatite and soapstone, I include in them all those soft unctuous rocks, useful for economical purposes, which are composed almost entirely of talc. And my object is not to give any farther account of those extensive and numerous depositesof this substance in

Massachusetts which are described in my former report, but merely to notice a few new localities.

No. 214 is a specimen of laminated green talc from Fitchburg. I am told that the bed is four feet thick, and most of it of a much finer grain than this specimen. A smaller specimen sent me is nearly compact. If enough of either kind can be obtained, free from foreign minerals, there is no doubt but it may prove valuable.

Dr. Anthony Jones, of Newburyport, informs me, that he has discovered and owns a bed of soapstone on the banks of the Merrimack, two miles west of that place. But as I have seen neither a specimen nor the locality, I can say nothing more respecting it.

The most interesting and important locality of this rock, not formerly described, is in the east part of Andover, four miles from the Theological Seminary. The bed lies in hornblendic gneiss, whose stratification is very irregular and indistinct; but I ascertained its direction to be almost N. E. and S. W. and its dip large, corresponding in both respects with the great deposite of gneiss extending diagonally across the state. The bed is not less than 50 feet thick; and has been opened by the proprietors, Flint, Jenkins & Co., several rods in length. They have wrought it for a variety of purposes, and it admits of being smoothed so as to appear well. Its composition is remarkably uniform, consisting essentially of rather hard foliated talc, though occasionally a black mineral is disseminated through it, which appears to be hornblende. Its strength appears to be greater than marble; as the proprietors informed me that a square piece 2 inches thick, laid on two supports 18 inches apart, sustained 800 pounds, laid upon a spot in the centre only half an inch wide; 860 pounds broke it.

The specimen No. 213 gives no idea of this rock, except as it is newly broken from the quarry. The proprietors, however, inform me, that one or two monuments made from it, have been placed at Mount Auburn. And for such a purpose it seems well adapted. I cannot but believe that this rock, which is certainly a peculiar one, and quite different from ordinary soapstones, will ere long come into extensive use, and the enterprizing proprietors be rewarded for their expense and perseverance. It seems applicable to nearly every use for which marble is employed.

Large boulders of this rock are scattered over a considerable space around the quarry, in an east and west direction, and since the diluvial current in this region was from the north, these boulders render it probable that the bed is far more extensive than the spot which is opened ; or that other beds occur beneath the surface.

22. Serpentine or Verd Antique Marble.

A remarkably interesting bed of serpentine has been recently discovered in the town of Lynnfield, near the centre of the place, where a quarry has been opened. The proprietor, Mr. James C. Nichols, informs me that he has traced the bed in a north-east direction from this spot two or three miles. Where it crosses the county road leading from North Reading to Salem, about a mile and a half from the quarry, a large quantity was blasted out, which was too hard to be wrought without great difficulty. The bed has not been traced far to the south-east of the quarry, as the rocks are mostly concealed by diluvium. But the great quantity of serpentine blocks scattered in a rather south-west direction for two or three miles, show that it does extend that way a considerable distance : while their great number gives us a striking idea of the extent of the whole bed. There can be no such thing as exhausting it. Its width in some places is not less than nine or ten rods.

Although on the Geological Map of the State I have represented sienite as existing at the centre of Lynnfield, yet from the direction of the bed of serpentine, as well as the character of the diluvium, I am satisfied that it is embraced in the great gneiss formation whose strata run from north-east to south-west across the state. Probably the bed is not far from the eastern limits of this formation.

This serpentine, for the most part, appears to form that variety which goes by the name of Verd Antique Marble. When first quarried, "it is much softer," says the proprietor, "than any marble I have seen. It can be cut with a handsaw, or turned in a lathe, nearly as easy as *lignum vitae* ; but while in this soft state it will not receive so high a polish." The specimen No. 215, which was polished and presented to the state collection by Mr. Nichols, will give an idea of common specimens of this stone. He says that "this

serpentine can doubtless be wrought with less expense than common marble. We have made but a small opening, yet we have obtained some sound slabs five feet in length; and we shall doubtless find the stone sufficiently sound to afford slabs large enough for any ordinary purpose. We have not manufactured much of the stone, nor offered any for sale: yet we have full confidence that it would find a ready market."

Should it prove that this serpentine can be afforded at a cheaper rate than marble, I cannot see why it must not come into extensive use in all cases where a stone of a dark shade is preferred; though there will doubtless be found on exploration, pieces of various shades. The situation of the quarry so near the sea board, and in proximity with several of the largest towns of New England, is an additional reason why I look upon the discovery as one of much promise.

Dr. C. T. Jackson has analysed this serpentine with the following results:

Silica,	37
Magnesia,	42
Oxide of Iron,	2
Water,	15
Loss,	4
	100

Dr. Jackson suggests, that Epsom salts (sulphate of magnesia) and carbonate of magnesia, may be manufactured from this rock: and he says that from 100 grains of the rock he prepared 127 grains of dry sulphate of magnesia, which, when crystalized, will form 178 grains of Epsom salts. This will give, by decomposition with the carbonate of potassa or soda, 98 grains of the common carbonate of magnesia of the shops. A similar suggestion might be made in respect to the many other beds of serpentine in the state.

I here close my Report: not because I have exhausted the materials in my hands; but because some other points, which I would gladly have presented, have been examined by me too little to enable me to offer any remarks upon them that will be of importance. I have been surprised at the number of new objects of interest and

value that have continued to offer themselves to my attention, up to the very day on which I close this Report. If I have presented results enough to satisfy the Government that a re-examination of our geology was not a useless labor, and that still farther developements may be expected, of pecuniary importance, as the fruit of still farther researches, I shall be satisfied. And should they wish me to prosecute my inquiries to a more mature result, I shall rejoice, if a kind Providence permit, to resume the labor ; in the confident belief, that whoever contributes, even in the feeblest measure, to the prosperity of our beloved Commonwealth, is indirectly promoting the welfare of the whole human family.

Most respectfully submitted,

EDWARD HITCHCOCK.

Amherst College, April 1st, 1838.